RESTRICTED

See Page X

ST. LAWRENCE RIVER PROJECT

FINAL REPORT

1942

MAIN REPORT

CORPS OF ENGINEERS, U.S. ARMY

U.S. ENGINEER OFFICE · MASSENA, NEW YORK.

ST. LAWRENCE RIVER

PROJECT

* * * * *

FINAL REPORT

1942

MAIN REPORT

CORPS OF ENGINEERS, U.S. ARMY

U.S. Engineer Office - Massena, New York

APRIL 1942

U.S. Army. Corps of Engineers

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[redacted]

Regraded UNCLASSIFIED

Authority Executive Order 10501

This report contains much information about present and proposed transportation routes, generating stations, transmission lines and manufacturing installations which are vital to the war effort. This information might be of great value to enemy agents planning bombing or sabotage operations. Accordingly the War Department has classified the report as "RESTRICTED". Publication or reproduction of any part of this report or of any of its appendices, plates or maps is prohibited. The Army Regulations regarding the dissemination of "restricted" matter read as follows:

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A B Jones

A. B. JONES,
Colonel, Corps of Engrs., U. S. Army
District Engineer.

WAR DEPARTMENT
United States Engineer Office
St. Lawrence River District
Massena, N. Y.

April 30, 1942.

Subject: Report on Proposed St. Lawrence River Project (International Rapids Section).

To: The Chief of Engineers, U. S. Army, Washington, D. C.

CHAPTER I - INTRODUCTORY

1. a. I submit herewith my report on the proposed navigation and hydroelectric power development in that portion of the St. Lawrence River known as the International Rapids Section, comprising approximately 46 miles of river between Chimney Point (near Ogdensburg) and St. Regis, New York. The engineering investigation was undertaken in response to your directive and the provisions of Executive Order No. 8568 issued October 16, 1940. The report consists of four chapters supplemented by a number of appendices thereto.

b. The proposed project contemplates the development of approximately 2,200,000 horsepower of hydroelectric power and provision of a navigation channel having a minimum depth of 27 feet throughout the reach. It will be accomplished by construction of dams, powerhouses, locks, canals, dikes, and by channel excavation where necessary.

c. The following general plates are bound herein:

M General Map of St. Lawrence River System.

M-I General Plan, Controlled Single-Stage Project, 238-242, Recommended Plan (1942).

M-IA General Plan, Controlled Single-Stage Project, 238-242, Alternate Plan (1942).

M-II General Plan, Controlled Single-Stage Project, 238-242, Original Plan (1940).

M-III Profiles, Controlled Single-stage Project, 238-242.

d. The preliminary explorations and preparation of preliminary plans and specifications assigned to the Corps of Engineers under the following authorizing directives have been completed.

2. AUTHORIZING DIRECTIVES. - a. Executive Order No. 8568. - On

October 16, 1940, the President issued Executive Order No. 8568, which reads as follows:

'By virtue of the authority vested in me by the act entitled "An Act making appropriations for the Navy Department and the Naval Service for the fiscal year ending June 30, 1941, and for other purposes', approved June 11, 1940 (Pub. No. 588, 76th Cong.), and by the Military Appropriation Act, 1941, approved June 13, 1940 (Pub. No. 611, 76th Cong.), and as President of the United States, and in order to provide for emergencies affecting the national security and defense, it is hereby ordered as follows:

"1. There is hereby established the St. Lawrence Advisory Committee, consisting of Leland Olds, Chairman of the Federal Power Commission, as Chairman; A. A. Berle, Assistant Secretary of State; Brigadier General Thomas M. Robins of the Board of Engineers for Rivers and Harbors, Corps of Engineers, United States Army; and Gerald V. Cruise, representative of the Trustees of the Power Authority of the State of New York. It shall be the duty of the Committee to advise the President with respect to the matters hereinafter set forth, and to perform such other functions as the President may determine.

"2. The Federal Power Commission and the Corps of Engineers, United States Army, are authorized, empowered, and directed....

"(a) To make such preliminary investigations as the Advisory Committee may consider appropriate or necessary with respect to development of navigation and hydroelectric power in the International Rapids Section of the St. Lawrence River, including among other things, (1) preliminary investigations of the potential dam site by means of core borings, test pits, soil analyses, etc., (2) preliminary surveys of lands necessary for such development, and investigation of the titles to such lands, and (3) preparation of preliminary plans and specifications.

"(b) To make periodic reports, with recommendations to the President, of the results of the aforesaid investigations.

"(c) To consult and cooperate with appropriate agencies of the Canadian Government.

"3. In the performance of their functions and duties under this order the Federal Power Commission and the Corps of Engineers, United States Army, may avail themselves of

the services, records, reports, and information of the executive Departments and other agencies of the Government.

"4. The Federal Power Commission and Corps of Engineers, United States Army, shall have authority to appoint, without regard to the civil service laws, such officers, experts, and employees as they may deem necessary to carry out their functions under this order, and to prescribe their functions, duties, responsibilities, and tenure.

The White House
October 16, 1940 Franklin D. Roosevelt."

b. Allotment of Funds.- On October 10, 1940, the President transmitted a message to Congress stating among other things that he had allocated $1,000,000 from special defense funds for carrying out the preliminary work authorized in the Order. This message was printed as House Document No. 978, 76th Congress, 3rd Session, and a copy is included in Appendix A-2. On the same date, the President sent a letter to the Secretary of War requesting that the preliminary engineering work of the Corps of Engineers be initiated immediately and informing him that funds in the amount of $50,000 and $950,000 were being allocated to the Federal Power Commission and to the Corps of Engineers, respectively, for their investigations. The Secretary of War replied that the Chief of Engineers was providing for immediate initiation of the work and its completion without delay. The first allotment of funds was supplemented by an additional allotment of $400,000 which was made available on December 24, 1941.

c. St. Lawrence River District.- The Chief of Engineers by General Orders No. 5 dated October 25, 1940, established a special engineer district known as the St. Lawrence River District, detailed an officer of the Corps of Engineers to act as District Engineer, and directed that the field work assigned to the Corps of Engineers by the aforementioned Executive Order be undertaken without delay. General Orders No. 14, O.C.E., dated April 11, 1942, abolishes the St. Lawrence River District, effective May 1, 1942. The work assigned having been accomplished by this district, the records and files will be transferred to the New York District, New York, N.Y.

3. THE MISSION OF THE ST. LAWRENCE RIVER DISTRICT.- a. In accordance with the foregoing directives, the assembling of an engineering and executive organization was begun immediately and district headquarters were opened in Massena, New York, on November 4, 1940. The Federal Power Commission received about four per cent and the Corps of Engineers about ninety-six per cent of the funds provided for this work. The assignment of engineering work by the Advisory Committee has been in a somewhat similar ratio between the two organizations.

b. The United States Advisory Committee held joint meetings with the corresponding Canadian Committee and the "Original 238-242 Plan" as described in paragraph 10 and shown on Plate M-II bound herein, was

accepted as the general plan for study. General instructions as to the work to be undertaken were issued.

c. The District Engineer immediately began negotiations with contractors for subsurface explorations, and a negotiated unit price contract was entered into with Sprague & Henwood, Inc. of Scranton, Pennsylvania. A contract was entered into with the Harza Engineering Company of Chicago, Illinois to make designs and prepare plans and specifications for the powerhouse and necessary equipment.

d. The other work, including the following major items, was undertaken by Government forces.

(1) General studies of all related problems.
(2) Design and preparation of plans and specifications for the Long Sault and the Iroquois Point Dams.
(3) Studies and preparation of plans and specifications for all navigation facilities, including those necessary to maintain the existing 14-foot navigation during the construction period.
(4) Inspection and supervision of all contract work.
(5) Collection of all existing data and surveys to obtain additional necessary information.
(6) Purchase and erection of a cableway to provide access to Barnhart Island during the winter.

e. Considerable difficulty was experienced in obtaining suitable personnel due to the unusual activity throughout the country in connection with national defense. An organization of approximately 300 members was finally assembled. Great credit is due to the employees of the District who endured unsatisfactory housing conditions during the severe winter of 1940-1941 and at the same time gave their best efforts to the work.

f. Studies of each principal feature of the proposed project works were undertaken to determine all pertinent facts. Surveys and subsurface explorations were carried out to provide detailed information regarding foundation conditions not only at the sites tentatively selected in the report but at numerous alternate sites, in order that the best location could be selected. Alternate designs and cost estimates were worked out and the most desirable plan was selected by comparison and elimination. Canadian engineers and several consultants joined in these discussions.

g. Certain items such as acquisition of land and rehabilitation measures on the Canadian side, which by the terms of the agreement are to be handled by the Canadian Government, were not studied in detail; however, through contact with Canadian officials these items received sufficient consideration to assure that the proposed plans are satisfactory with respect to these items. It has been the aim of the District Engineer to perfect the plans, complete the designs, and prepare contract drawings and specifications so that contracts for the principal work items could be entered into with the least possible delay

when authority for the work is received.

h. Since under the International Agreement of March 19, 1941, all contracts require approval of the Great Lakes - St. Lawrence Basin Commission, (see paragraph 10a) none of the engineering decisions recorded in this report and none of the plans and specifications accompanying it can be considered final, but should be considered merely as the recommendation of the District Engineer. Every effort has been made to assure that all features herein presented are satisfactory to the Corps of Engineers and to the Department of Transport. It is believed that the presentation of this report to the Great Lakes - St. Lawrence Basin Commission will assist that body and will expedite the construction of the proposed project.

4. ARRANGEMENT OF REPORT. a. Report.- The report consists of two principal divisions; (1) the report proper, and (2) the appendices. An attempt has been made to limit the report to concise and yet complete statements covering work performed and containing only such general maps and plans as are necessary for intelligent reading. Detailed plans, specifications, analyses of design, maps and cost estimates form the appendices. All other general data such as maps, charts, previous reports, printed matter, and field notes are contained in the St. Lawrence River District files. These data, which have been indexed, are readily available for future reference. The report proper consists of four Chapters as shown below:

(1) CHAPTER I - INTRODUCTORY

General information; authority for the work; description and geology of the region; previous reports; basic plan.

(2) CHAPTER II - SURVEYS, STUDIES AND INVESTIGATIONS

Previous available data; new data; availability of construction material, particularly concrete aggregates; design criteria; transportation facilities; organization for construction; and housing and related problems.

(3) CHAPTER III - PROPOSED PROJECT WORKS

Description of plans and sequence of construction for each major subdivision (designated as "feature" in this report) with estimates of the time required for construction.

(4) CHAPTER IV - ESTIMATES

Complete estimates of cost for the entire project with discussions and comparisons with other plans and estimated expenditures by fiscal years. Unit prices of material and wage scales used in preparing the estimates of cost are generally those existing as of the summer of 1941. Allowances of 18, 21 and 25 per cent have been included for engineering and contingencies as indicated in the estimates of the various features.

b. Appendices.- The general scheme for the appendices is that those of a general nature are designated by capital letters and those which pertain to one or a few features in the report proper are designated by the same numeral as the corresponding feature in the report; for example, an appendix pertaining to Feature No. 15 of Chapter III is designated as Appendix III-15. An effort has been made to arrange the appendices so that complete data will be available for further detail study of the matter and to show the work performed, the methods used, and the results obtained.

c. Priorities.- As a rule, plans and specifications prepared during the calendar year 1941 were based on the priorities and prohibitions regarding the use and availability of materials in effect at the time. Since the entrance of the United States into war, it has been impossible to revise the plans and specifications to conform with the changing status of priorities and prohibitions. If construction of the project is undertaken under these abnormal conditions, it will be necessary to revise the plans and specifications to adapt them to conditions which may exist during the construction period.

d. Status of Completion of Work Items.- When this work was started, it was anticipated that the International Agreement would be ratified and construction of the proposed project would be authorized before the funds allotted were exhausted and that preliminary work could be merged with construction. Since the agreement has not been ratified and funds are exhausted, preliminary work has been carried to the various stages of completion hereinafter indicated. In some cases complete plans and specifications have been prepared, revised and approved by the Chief of Engineers, and invitations for bids for a construction contract could be issued immediately. At the other extreme there are items where all that could be presented at this time is a statement of the problem and an outline of the proposed method of procedure.

5. GENERAL DESCRIPTION OF THE ST. LAWRENCE RIVER SYSTEM.- a. A glance at the map of North America reveals that the St. Lawrence River System (see Plate M bound herein) comprises:

(1) All of the five Great Lakes, namely, Lakes Superior, Michigan, Huron, Erie, and Ontario with their drainage areas and connecting waterways.

(2) The St. Lawrence River proper from Lake Ontario to the Gulf of St. Lawrence, with tributaries.

b. The total drainage area above the foot of the International Rapids Section at St. Regis, New York is approximately 303,000 square miles, of which 95,000 square miles are water surface. The stream is unique among rivers of the world in that the tremendous storage capacity of the lakes within the watershed regulates the flow in the river to an unusual extent; the maximum average monthly outflow at the outlet of Lake Ontario being about 314,000 cubic feet per second, the observed average mean monthly outflow from 1860 to 1940 inclusive, 237,000 cubic

feet per second and the minimum 144,000 cubic feet per second.

c. The St. Lawrence River System, in conjunction with the Gulf of St. Lawrence, provides a continuous waterway extending 2,347 miles into the heart of the Continent from the Atlantic Ocean at the Strait of Belle Isle to Duluth, Minnesota. The first 843 miles between the Atlantic Ocean and the city of Quebec is through the Gulf of St. Lawrence which is salt water terminating in a tidal estuary extending up to the City of Quebec. The St. Lawrence River from Quebec to Lake Ontario, comprising approximately 342 river miles, is one of the larger rivers of the world based upon volume of flow, but the channel is subdivided by hundreds of islands and the slope broken by numerous rapids which, under original conditions, were severe barriers to navigation. From the foot of Lake Ontario to Duluth, the sailing distance is 1,162 miles and to Chicago 1,061 miles, by way of the five Great Lakes and their connecting channels. Generally speaking, the main bodies of the Great Lakes have ample depth for all classes of navigation, but the connecting waterways in their original condition presented more or less complete barriers to the passage of vessels. The connecting channels are Niagara River containing Niagara Falls and the Whirlpool Rapids between Lakes Ontario and Erie (Welland Canal used by navigation); the Detroit River, Lake St. Clair and St. Clair River between Lakes Erie and Huron; the St. Mary's River with the locks at Sault Ste. Marie, between Lakes Huron, Michigan and Superior; and the Straits of Mackinac between Lakes Huron and Michigan.

d. The drainage area tributary to the Great Lakes consists of a comparatively narrow belt of land extending around the Lakes and including practically all of the two peninsulas of the State of Michigan. The region along the United States side is generally well developed from both an agricultural and industrial standpoint and includes the important cities of Buffalo, New York; Cleveland, Ohio; Detroit, Michigan; Chicago and environs, Illinois; Milwaukee, Wisconsin; and Duluth, Minnesota, as well as many other smaller cities. The region on the Canadian side north of Lakes Superior and Huron is in general more barren, glaciated terrain with bedrock exposed in many areas, while the Canadian territory north of Lakes Erie and Ontario and along the St. Lawrence River is well developed agriculturally with many important industrial centers, including the cities of Montreal, Toronto, Hamilton, Welland and Windsor. The entire region is well supplied with first-class highways and railroads, and commercial navigation facilities on the Lakes are of first importance. The waterways between Lakes Superior and Huron and Lakes Huron and Erie carry many times more tonnage than any other inland waterways in the world. The total tonnage passing through the Soo locks during 1941 exceeded 110,000,000 tons. The total traffic of Detroit River during 1941 exceeded 128,000,000 tons. The waterborne commerce consists principally of iron ore, coal, and grain. A large fleet of vessels especially designed for conditions existing on the Lakes is engaged in this commerce. The present controlling depths in the waterways of the St. Lawrence River System are as shown in the following tabulation.

NAVIGABLE DEPTHS
ST. LAWRENCE RIVER SYSTEM

Section	Name of Waterway	Approx. Mileage	Present Controlling Depth	Proposed Depth	Remarks
Duluth, Minn. to foot of Lake Superior (Point Iroquois)	Lake Superior	383	Greater than 27 feet	Same	Ample depth for any class of navigation.
Foot of Lake Superior (Point Iroquois) to Lake Huron (Detour)	St. Mary's River	63	20.6 up-bound 22.3 down-bound	27 ft.	Includes Soo Locks.
Through Lake Huron (Detour to Port Huron)	Lake Huron	223	27 ft.	27 ft.	Depth is generally greater than 27 ft.
Chicago, Ill. to foot of Lake Huron (Port Huron)	Lakes Michigan and Huron	568	27 ft.	27 ft.	Depth is generally greater than 27 ft.
Port Huron to Lake Erie (Detroit River Light)	St. Clair River, Lake St. Clair and Detroit River	90	20 ft. up-bound 25 ft. down-bound	27 ft.	
Through Lake Erie (Detroit River Light to Port Colborne)	Lake Erie	218	27 ft.	27 ft.	Depth is generally greater than 27 ft.
Lake Erie (Port Colborne) to Lake Ontario (Port Weller)	Welland Canal	27	25 ft.	27 ft.	Depth over lock sills is 30 ft.
Through Lake Ontario (Port Weller to Tibbets Pt.)	Lake Ontario	157	27 ft.	27 ft.	Depth is generally greater than 27 ft.
Lake Ontario (Tibbets Pt.) to Chimney Point	1000 Islands section of St. Lawrence River	68	27 ft.	27 ft.	Chimney Point is upstream end of Inter-

					national Rapids Section.
Chimney Point to St. Regis, N.Y.	International Rapids Section of St. Lawrence River	46	14 ft.	27ft.	St. Regis is downstream end of International Rapids Section
St. Regis to Montreal, Que.	Canadian Section of St. Lawrence River	68	14 ft.	27ft.	All-Canadian Section of St. Lawrence River.
Montreal, Que. to Quebec. Que.	Canadian Section of St. Lawrence River	160	32.5 ft.	35ft.	All-Canadian Section of St. Lawrence River
Quebec, Que. to Atlantic Ocean (Strait of Belle Isle)	Gulf of St. Lawrence	843	Greater than 35 ft.	Same	Tidal Water.

Note: Navigation between ocean and lake ports is limited to vessels suited to the available dimensions in six canals around rapids of the St. Lawrence River between Montreal, Que., and Ogdensburg, N. Y., the locks of which have controlling dimensions of 252 feet in length, 44 feet in width, and depth of 14 feet over sills. The limiting vertical clearance at high level fixed bridges over St. Lawrence River is 150 feet, and under vertical lift bridges over the Welland Ship Canal, between Lake Ontario and Lake Erie, is 120 feet; the width of channel through bridges exceeds the limiting widths in canal locks. In the connecting rivers and ship channels which govern navigation between Lakes Ontario, Erie, Huron, Michigan, and Superior, the available depth is at least 20 feet for up-bound traffic and at least 22 feet for down-bound traffic; the only canal navigation is in the Welland Ship Canal between Lakes Ontario and Erie with locks having usable length of 765 feet and width of 80 feet, and in St. Mary's River near Lake Superior with locks having usable length of 1,300 feet and width of 80 feet.

6. REGIONAL GEOLOGY.- a. General.- The St. Lawrence Valley is a region of low relief which has been considerably modified by glaciation and invasion by the sea. The valley is almost entirely within the St. Lawrence Plain which stretches between the Adirondack Highland of New York and the Canadian Highland of Ontario and Quebec. From Lake Ontario to a point in the vicinity of Brockville, Ontario, the underlying bedrock consists of precambrian crystalline formations which constitute

a narrow isthmian-like connection between the very large masses of such rocks in the highlands just mentioned. Downstream fron the easterly edge of this connecting belt in the vicinity of Brockville, the St. Lawrence Plain varies from 60 to 70 miles in width and is underlain by flat-lying, early paleozoic sedimentary rocks. The St. Lawrence River constitutes the main drainage of the region and the principal tributaries in the area under consideration are the Oswegatchie, Grass, Racquette, and St. Regis Rivers on the south and the Ottawa River on the north. Few lakes are found in the valley, but many swamps and marshes occur in the wide, flat lowlands. A detailed description of the geological conditions revealed by field and laboratory investigations is contained in the reports and analyses of design pertaining to the various features which are included in the appendices.

b. Overburden.- Compact till or hard pan, composed of unstratified, clayey to silty, gravelly sand with scattered boulders, covers the bedrock in most of the region. This till formed the bottom of the ice sheet during the glacial period. The glacial till is believed to be entirely suitable for both foundations and as material for earth fill or embankments and dikes. It is sufficiently compact so that no appreciable settlement would be expected under heavy loads. It is unstratified and probably would be relatively impervious and stable under all conditions where used as foundations for earth fills and dikes. The ice sheet which formed this till apparently advanced over the region from the northeast and plowed up the old residual soil and loose rock which had accumulated in the valley as a result of long ages of weathering. It is probable that some of the material picked up was incorporated into the main mass of ice so that when the ice finally melted, this material was deposited on the underlaying hard pan and formed deposits of looser, more sandy upper till, which ranged from clayey, gravelly sand with scattered boulders to silty sand and gravel with boulders. During the recession of the ice, the Adirondack Highland probably emerged from the thinning ice sheet in the St. Lawrence Valley, thus forming a dam at the main drainage outlet. A large lake, known as Lake Iroquois, was thereby impounded in the Ontario basin having its outlet near Rome, New York, where the overflow spilled down the Mohawk Valley to the sea. As the ice oover reoeded to the north, a lower outlet for the lake was unoovered at Covey Hill, Quebec, which for a time allowed the overflow to pass down the Champlain and the Hudson Valleys. Great delta deposits were formed at various stages of Lake Iroquois at points along the shore where rivers from the Adirondack Highland entered the lake. Remnants of these vast delta deposits still exist in the vicinity of Booneville, Lowville, Parishville, and Malone, New York, and the elevations of their surface indicate the depth of Lake Iroquois as well as the uplift since that time. Apparently the conditions of the ice-edge during the recession were such that no extensive aqueo-glacial deposits were formed. Lake Iroquois disappeared when the ice had melted sufficiently to uncover the Gulf of St. Lawrence. The land was apparently depressed below sea level by the tremendous weight of the ice sheet, and as the ice disappeared, sea water occupied the St. Lawrence Valley to form what is known as the Champlain Sea. The topography of the valley at that time was characteristic of glaciated regions; low elongated, lenticular hills and ridges, with a general northeast-southwest trend, covered the entire

region. The highest of these hills and ridges projected above the water surface to form innumerable islands in the inland sea. Waves and currents cut into the exposed hills forming beaches of glaciated material while the finer sand, silt and clay was deposited in the valleys between the hills. Material from rivers flowing from the Adirondack Highland was also laid down on the bottom of the sea. Thus the irregular rough topography left by the ice was modified and subdued as the deeper portions of the valleys were filled and the lower hills were buried beneath the marine silt and clay. The marine clay as found today varies from a fairly stiff consistency in some areas and zones to a soft semi-liquid consistency in other areas and zones. As the land slowly rebounded after relief from the ice load, the water shoaled and deposits of fine sand were spread over the clay and silt to form the wide sand plains such as those located in the vicinity of Waddington, New York and at many points north of the river in Canada. The land apparently continued to rise and the marine estuary gradually assumed the outline of the present Gulf of St. Lawrence. The present topography of the St. Lawrence Valley is essentially the same as when it emerged from the sea, except that a haphazard drainage system with the rivers flowing in the sand and clay filled valleys between the hills of till has developed. The drainage is almost entirely drift controlled and at only relatively few places have the streams encountered bedrock in their courses. Wherever bedrock has been encountered, rapids are formed as, for example, at Galop Island and Long Sault in the St. Lawrence River.

c. Bedrock.- The bedrock of the valley downstream from Brockville, Ontario is a series of early paleozoic sedimentary rocks overlying the Greenville and other Pre-Cambrian crystalline rocks. The only formations which occur at the surface of the bedrock under the river channel between Ogdensburg, New York and Valleyfield, Quebec, are the Beekmantown and Chazy formations of Ordovician age. The area is covered with a thick blanket of drift, therefore rock exposures are uncommon and the tracing of exact formation boundaries is practically impossible. Fossils are rare in the Beekmantown formation, but are plentiful at some horizons in the Chazy. The Beekmantown formation consists chiefly of dolomite with occasional thick strata of sandstone, limestone, and shale. The chazy formation is more variable and consists of dolomite interbedded with numerous strata of shale, limestone, and sandstone. Small deposits of gypsum occur in the upper Beekmantown and lower Chazy formations. The strike of the formations trends northeast-southwest in the vicinity of the river and dips very gently toward the northwest. It appears that the ice removed all of the weathered rock in the area so that the present bedrock is fresh, hard, and solid. In addition to the almost horizontal bedding planes, the rock is cut by joints which intersect the bedding at various angles.

d. Faulting.- A few faults are known to occur within the project area. They appear to be part of a large system of similar faults which have been mapped throughout the surrounding region. This region has undergone progressive uplift since early post-glacial times and there is evidence that such uplift is still occurring. Earthquakes of feeble or mild intensity are rather common in the St. Lawrence plain,

but are infrequent in the adjoining regions of the Adirondacks and the Laurentian shield. The recorded seismic disturbances upstream from Montreal have varied from slight vibrations to shocks of moderate intensity, while more intense shocks have occurred in the valley downstream from that city. No earthquakes of destructive magnitude have been recorded in the vicinity of this project during historic times. Nevertheless, the possibility of future movement along these old fault planes cannot be disregarded and this possibility has been considered in the studies.

7. <u>THE INTERNATIONAL RAPIDS SECTION OF THE ST. LAWRENCE RIVER.</u>- a. The International boundary between Canada and the United States follows the river from Lake Ontario to a point in the channel in the vicinity of St. Regis, New York, then strikes inland on the United States or southerly side of the river. (See Plate No. M-1 bound herein.) The river channel downstream from St. Regis, New York is entirely within Canadian territory, and the reach between St. Regis and Lake Ontario has an International status. The portion of the river from Lake Ontario to Chimney Point, a few miles below Ogdensburg, New York, is commonly referred to as the "Thousand Islands Section" while the "International Rapids Section" comprises the reach, approximately 46 river miles, between Chimney Point and St. Regis, New York. The portion of the river below St. Regis is called the "Canadian Section." The total fall within the International Rapids Section is approximately 92 feet at mean river stage, the greater portion of which is concentrated in three main breaks in the flow line; namely, (1) the famous Long Sault Rapids located in the vicinity of Long Sault Island, several miles upstream from Cornwall, Ontario; (2) the Rapids Plat Section in the vicinity of Ogden Island, just upstream from Morrisburg, Ontario; and (3) the Galop Rapids in the vicinity of Galop Island located a few miles downstream from Chimney Point. The break in the flow line at Galop Island is in reality the control for the level of the water surface in Lake Ontario. This break is caused by the passage of the river over a ridge of hard rock, with a general north-south strike, which crosses the area. The Thousand Islands Section between this point and Lake Ontario has very little slope and such low velocity that it is practically an extension of the lake. It, therefore, follows that the effect on the levels of Lake Ontario must be given careful consideration in connection with plans for changes in the discharge through the Galop Island Section. A 27-foot channel has been provided throughout the Thousand Islands Section; each country performed the necessary dredging within its boundary. The numerous islands in the channel through the International Rapids Section, cause many back channels and cross channels, creating hazards to navigation. The flow in this section of the river is generally swift, reaching velocities as great as 12 miles per hour at some points. A series of lateral canals, providing a 14-foot navigable depth along the Canadian side of the International Rapids Section, and bypassing the steeper portions of the section, was constructed by the Domininion of Canada early in the present century. These canals, which still constitute the avenue of water-borne commerce between the Great Lakes and Montreal, contain several locks with the following controlling dimensions: length, 252 feet; width, 44 feet; and depth over sills, 14 feet.

b. Within the International Rapids Section, the geologic formation, in general, consists of glacial till ranging in thickness from a few feet up to 200 feet or more, including thick beds of marine clay in many localities. These formations overlie the bed rock which is generally uniform in contour but broken by gentle valleys and ridges, with a general north-south strike, which are in turn intersected by depressions from pre-glacial drainage channels. The glacial till consists principally of clay, sand, gravel, and boulders intermixed in irregular manner. The bed and banks of the stream are in general paved with large boulders and are not subject to erosion. This condition, together with the great storage capacity of the lakes in the watershed, renders the river water unusually free from silt. The winter climate is severe. Sub-zero temperatures are common and heavy ice covers form wherever the conditions of flow permit. The ice problem is an important factor in the design of any hydraulic structures in this region and this matter is fully considered in paragraphs pertaining to the design of such structures.

8. PREVIOUS STUDIES AND REPORTS.- a. General.- The St. Lawrence River System, including the Great Lakes, has always been an important water route from the time of the early explorers, and numerous attempts to provide improvements for navigation have been made by private interests and by State, Provincial, or Federal Governments. These efforts were reduced to a more systematic basis in the year 1895 when the United States Deep Waterways Commission was established by the United States Government, and instructed to confer with a similar organization set up by Canada for the purpose of studying the entire question of providing a deep water route from the Great Lakes to tidewater. This Commission submitted a report in 1897 (House Document No. 192, 54th Congress, 2nd Session) which discussed various possible routes and recommended that a definite survey be made and reliable cost estimates be prepared. A Board of Engineers, appointed in response to this recommendation, submitted a report in 1900 recommending a 21-foot waterway across the State of New York connecting with the Hudson River (House Document No. 149, 56th Congress, 2nd Session). This report included a fairly complete study of the improvement of the International Rapids Section of the St. Lawrence River for navigation only, without the development of power.

b. International Joint Commission - 1909.- A further forward step was taken in the year 1909 when a treaty between the two countries, which was signed on January 11, 1909, created a permanent International Joint Commission, composed of members from both countries, which had jurisdiction over all matters pertaining to the boundary waters between the United States and Canada. In 1919, Congress expressed a desire for investigation by the International Joint Commission of the question of improving the St. Lawrence River between Lake Ontario and Montreal, Quebec. The following year both Governments referred the question to the International Joint Commission and designated a joint engineering board consisting of Colonel W. P. Wooten, Corps of Engineers, United States Army, and W. A. Bowden, Chief Engineer, Department of Railways and Canals of Canada, to work with the Commission and provide the necessary expert engineering assistance.

c. Wooten-Bowden Report - 1921.- The Wooten-Bowden Board submitted its report to the International Joint Commission on June 24, 1921, which was published as Senate Document No. 179, 67th Congress, 2nd Session. That report contained the following principal conclusions and recommendations.

(1) That physical conditions on the St. Lawrence River between Montreal, Quebec, and Lake Ontario, were such that improvements for navigation which will be permanent in character and will have a very low upkeep cost could be installed, but improvement for navigation alone was not recommended because of the great loss which would result from failure to develop approximately 4,100,000 horsepower of potential hydroelectric power within the reach.

(2) That the development of this vast quantity of power was not justified because of lack of market and that only a part thereof should be developed at that time.

(3) That a sound method of procedure would be to develop the International Rapids Section both for navigation and for power, providing a 25-foot navigation channel with 30-foot depths over the sills of locks; and to develop the other sections for navigation only, postponing the development of power to a future time as needed.

(4) That the estimated cost of doing this work would be;

First Division- Montreal Harbor to Lake St. Louis; development to consist of side canal for navigation only	$55,783,000
Second Division- Deep water in Lake St. Louis to deep water in Lake St. Francis; construction of side canals for navigation only..................	36,590,000
Third Division- Lake St. Francis; dredging where necessary for navigation................................	1,158,000
Fourth Division- International Rapids Section between St. Regis and Chimney Point; combined navigation and power development, including necessary channel excavation, canals and locks, and an installed capacity of approximately 1,850,000 horsepower................	159,097,200
Fifth Division- Thousand Islands Section from Chimney Point to Lake Ontario; dredging where necessary for navigation..........................	100,000
Total Estimated Cost.......	$252,728,200

(5) That under this plan of development a navigation depth of 30 feet throughout could be provided at a later date for an additional cost of $17,986,180.

d. The Wooten-Bowden plan contemplated the creation of a head of approximately 74 feet at the powerhouses by construction of a dam across the river at the downstream end of Long Sault Island, with a control dam located in the vicinity of Ogden Island to regulate the outflow from Lake Ontario and to provide satisfactory navigation between the control dam and Chimney Point. No installation for power at the control dam was recommended, although an effective head of approximately 8 feet would have been available during the summer. In the design of the main dam and related structures, provisions were to be made for increase in height at a future date to utilize the full available head.

e. International Joint Commission Report - 1921.- The International Joint Commission held public hearings on the subject and several alternative plans were presented. The Commission, on December 19, 1921, submitted its report on the matter. This report was transmitted to Congress with message of the President on January 16, 1922 (Senate Document No. 114, 67th Congress, 2nd Session). The report contained among other things the following general recommendations.

(1) That the two Governments enter into an agreement by way of a treaty for the improvement of the St. Lawrence River between Montreal and Lake Ontario, based upon the Wooten-Bowden report with the understanding that before any final decisions are reached, the report of that board, together with the several alternative plans presented during the public hearings, will be given further consideration by an enlarged engineering board composed of leading members of the engineering profession in both countries, in order that all phases of the question receive consideration commensurate with their magnitude and importance.

(2) That the new Welland Ship Canal be embodied in the scheme and treated as a part thereof.

f. Joint Board of Engineers Report - 1926.- In the spring of 1924, a new St. Lawrence Commission was set up consisting of nine members from each country. In response to the recommendation made by the International Joint Commission in its report of 1921, a Joint Board of Engineers, consisting of three members from each country, was established to act with this new Commission in studying all phases of the problem. The necessary funds were provided by each country, and through an exchange of notes in February and March, 1925, a set of instructions for the Board was agreed upon and issued. The Joint Board of Engineers held its first meeting in April 1925, and agreed upon a division of work between the two sections of the Board. Each section set up headquarters, secured the necessary personnel, and proceeded with its work. The entire Board held frequent meetings and on November 16, 1926, submitted its report which is contained in Senate Document No. 183, 69th Congress, 2nd Session. The Board failed to agree upon a plan for complete development of the International Rapids Section of the St. Lawrence River

and instead submitted two recommendations as outlined below.

(1) The United States members of the Board recommended a so-called Single Stage Plan, estimated at $235,000,000, the principal features of which are as follows:

A main dam with two powerhouses (total installation 2,326,000 horsepower) located at the downstream end of Barnhart Island, with the main channel south of Barnhart Island as a forebay.

A 27-foot channel for navigation following the channel south of Cornwall Island to the mouth of Grass River, thence through a canal containing two large locks, and re-entering the river at the upstream end of Barnhart Island.

The south Galop channel to be closed with a dam containing gates for regulations of flow, and an uncontrolled channel through Galop Island for navigation use.

(2) The Canadian members of the Board recommended what was known as a Two Stage Plan, estimated at $264,600,000, the principal features of which are as follows:

A main dam at the head of Barnhart Island.

Two powerhouses (1,808,600 horsepower total installed capacity) located at the downstream end of Barnhart Island with the channels north of Barnhart Island as a forebay.

A 27-foot channel for navigation following the channel south of Cornwall Island to the mouth of Grass River, thence through a canal containing two large locks, and re-entering the river near the middle of Long Sault Island.

A second dam with two powerhouses located at Ogden Island, 300,000 installed horsepower on the Canadian side and 105,600 horsepower on the United States side.

A lock for navigation at Ogden Island.

The south channel at Galop uncontrolled, for navigation use.

A hydraulic channel through Galop Island with gates for controlling the flow.

Crysler Island Two Stage Plan.- An alternate plan known

as the Crysler Island Two Stage Plan, estimated cost $269,400,000, was also submitted by the Canadian section of the Board in which it was proposed to locate the upper dam at Crysler Island, approximately 7 miles downstream from the location considered in the foregoing Two Stage Plan. Under this alternate plan, the upper dam with two powerhouses (approximately 299,000 horsepower installed capacity each) would constitute a continuous structure across the river at Crysler Island; a short canal containing one lock would be provided for by-passing navigation on the United States side; other works would be the same as in the original Two Stage Plan.

h. This report of the Joint Board of Engineers (November 16, 1926) was submitted to the new St. Lawrence River Commission which submitted its report, containing the report of the Joint Board of Engineers, to the President of the United States on December 27, 1926. The President transmitted these reports to Congress on January 3, 1927, and they are printed as Senate Document No. 183, 69th Congress, 2nd Session.

i. Great Lakes to Hudson River Waterway Report - 1926.- In a report on "Waterway from the Great Lakes to the Hudson River" transmitted to Congress on December 6, 1926, and printed as River and Harbor Committee Document No. 7, 69th Congress, 2nd Session, the Chief of Engineers, U. S. Army, pointed out the economy of providing a deep draft channel via the St. Lawrence River as compared with a route across the State of New York to the Hudson River. He also pointed out the value of power development in the St. Lawrence River and expressed the view that a waterway should be provided between the Great Lakes and the sea for ocean vessels.

j. Canadian Conference of Engineers Report - 1929.- After the November 16, 1926 report of the Joint Board of Engineers had been submitted, studies of the International Rapids Section were continued by a group of Canadian engineers consisting of the Canadian members of the Joint Board of Engineers and two engineers representing the Province of Ontario. A revised version of the Crysler Island Two Stage Plan (see paragraph 8 g) was developed and a report thereon was submitted by this group to the Secretary of State of External Affairs of the Dominion of Canada in 1929. The revised plan recommended was substantially the same as that of the alternate plan of the Canadian members of the Joint Board of Engineers with only minor changes in the water levels and in the location of powerhouses. This report, which is known as "The Report of the Canadian Conference of Engineers", was printed by the Canadian Government.

k. New York Plan - 1931.- An act by the State of New York, approved March 29, 1930, provided for the appointment of a Commission consisting of five members, "to devise and report a plan or plans for the development of hydroelectric power in the St. Lawrence River." The act specified that the Commission "study and report plans for the development and a form of contract for the sale of hydroelectric power to be generated at water power sites on the St. Lawrence River owned or con-

trolled by the People of the State", and submit a report to the Governor and the Legislature not later than January 15, 1931. An Advisory Board of Engineers was established to assist the Commission, and a report presenting a single stage plan known as the New York Plan for development of the International Rapids Section was submitted on January 15, 1931, and was printed by the State of New York. The principal features of this plan are:

(1) A main dam in the channel south of Barnhart Island and secondary dams or dikes closing the upper end of the two channels north of Barnhart Island.

(2) A spillway dam and two powerhouses located near the mouth of the Grass River at the head of the channel south of Cornwall Island; total installed capacity 2,200,000 horsepower, with a forebay extending across the United States mainland between the powerhouse and Robinson Bay.

(3) A 27-foot channel for navigation in the river channel north of Cornwall Island, with a double lift lock on Barnhart Island near the main dam mentioned in (1) above.

(4) The south Galop channel closed with a dam provided with gates for regulation of flow.

(5) An uncontrolled hydraulic channel through Galop Island for navigation use.

1. Reconvened Joint Board of Engineers Report - 1932.- On January 23, 1930, the Joint Board of Engineers which prepared the engineering report submitted on November 16, 1926, was reconstituted by the appointment of three new United States members and was requested to resume studies and to report on a mutually agreeable plan for improvement of the International Rapids Section of the St. Lawrence River. This Board submitted a report on April 9, 1932, providing for a Two Stage Plan substantially the same as the alternate plan developed by the Canadian members of the original Joint Board of Engineers and later modified by the Canadian Conference of Engineers. This plan was considered to be feasible and safe from an engineering point of view. Its cost was estimated at $274,742,000. This report (printed in Canada) served as a basis for negotiations for a proposed treaty. The proposed treaty, which provided for developments along the lines presented in the engineering report, was signed by representatives of both Governments on July 18, 1932.* The proposed treaty was submitted to the United States Senate but failed of ratification.

*Text contained in mimeographed press release issued by the Department of State on July 18, 1932; text is also published in record of hearing dated April 20, 1933, before the Committee on Interstate and Foreign Commerce, House of Representatives, 73rd Congress, 1st Session, on H. J. Res. 157.

m. With the message of the President to Congress on January 10, 1934, urging ratification of the so-called "St. Lawrence Treaty with Canada", the Chief Executive transmitted reports from four Government agencies relative to the engineering and economic advisability of the proposed Great Lakes - St. Lawrence Project (Senate Document No. 116, 73rd Congress, 2nd Session).

n. Department of Commerce Report-1940-41.- In 1940-41 the Secretary of Commerce submitted the following reports on the St. Lawrence Survey to the President. These reports were prepared by the Director, St. Lawrence Survey, Department of Commerce, and were published by the Government Printing Office.

- PART I. History of the St. Lawrence Project.
- PART II. Shipping Services on the St. Lawrence River.
- PART III. Potential Traffic on the St. Lawrence Seaway.
- PART IV. The Effect of the St. Lawrence Seaway Upon Existing Harbors.
- PART V. The St. Lawrence Seaway and Future Transportation Requirements.
- PART VI. The Economic Effects of the St. Lawrence Power Project.
- PART VII. Summary Report of the St. Lawrence Survey, including the National Defense Aspects of the St. Lawrence Project.

9. NEGOTIATIONS OF THE LAST FOUR YEARS.- a. In the spring of 1938, diplomatic conversations between the United States and Canada were resumed, and, in 1938, engineers of the Canadian Department of Transport again undertook active studies of the problem, with particular attention to that portion dealing with the improvement of the International Rapids Section of the St. Lawrence River, and developed what they called the "238-242" Controlled Single Stage Project. (See paragraph 10.)

b. In January 1940, a board of engineers representing Canada and the United States was requested by the two Governments to examine the various plans proposed for the development of the International Rapids Section of the St. Lawrence River. In October 1940, the Canadian Temporary Great Lakes - St. Lawrence Basin Committee and the United States St. Lawrence Advisory Committee were constituted by their respective governments, and at a joint meeting held in Ottawa, January 3, 1941, they received a final report from the board of engineers appointed the preceding year, in which the board presented a description and estimate of cost of the "238-242" Controlled Single Stage Project, and stated that, in the opinion of the board, this plan was "the best from an engineering and economic point of view, bearing in mind the requirements of navigation and power and the protection of down river interests." The joint committees thereupon submitted the engineers' report to the President of the United States and the Prime Minister of Canada, with the recommendation that "in the event that the Governments decide to proceed with the development of the International Rapids Section of the St. Lawrence River, the work to be undertaken in general accordance with the plan of the '238-242' Controlled Single Stage Project described therein."

c. Following the submission of this report, the diplomatic branches of the two countries continued negotiations with the assistance of the joint committees, and on March 19, 1941, an agreement was signed by the Governments of the United States and Canada providing for the construction of dams and power works in the International Rapids Section, and for the completion of a Deep Waterway throughout the Great Lakes-St. Lawrence River System. The President transmitted the text of the agreement to Congress with his message of March 21, 1941, which stated that the terms of the agreement contemplate that it shall be made effective by concurrent legislation of the Canadian Parliament and of the Congress of the United States. The text of the agreement is published in House Document No. 153, 77th Congress, 1st Session (see Appendix A-2). The River and Harbor bill introduced in the House of Representatives, H. R. 5993, 77th Congress, 1st Session, contained an item approving the aforementioned agreement and authorizing the United States to undertake its portion of the project outlined therein. This bill was not passed by the Congress.

d. The aforementioned agreement provides for the construction of the entire project from the head of navigation on the Great Lakes to tidewater and leaves the present equal division of water power in the rapids of the St. Mary's River unchanged. It makes special provision for changes in the division of power now in effect at Niagara Falls, leaves Canada with the sole right to develop the power of the Canadian Section of the St. Lawrence River, and provides for equal division of the potential power in the International Rapids Section. The agreement also provides that the necessary improvements in the connecting waters between Lakes Huron and Superior and between Lakes Erie and Huron, including a new lock at Sault Ste. Marie, shall be undertaken by the United States; that the deepening of the Welland Canal and the improvements in the Canadian Section of the St. Lawrence River shall be executed by Canada with the understanding that a 27-foot navigation channel through these reaches will be completed by 1948; and that the improvements within the International Rapids Section of the St. Lawrence River shall be carried out in accordance with the "238-242" Controlled Single Stage Plan and under the supervision of an International Commission, the cost of the various features in this section to be divided according to rules laid down in the agreement. This division of the work and cost is such that each country will pay approximately half of the cost of the entire project, credit being allowed for certain work already done by each country.

e. On March 19, 1941, an agreement was also made between the Canadian Government and the Province of Ontario under which, on payment of certain sums, the Canadian powerhouses will be operated and the power distributed and sold by the Hydro-Electric Commission of Ontario. A similar agreement is proposed between the United States and the State of New York whereby the New York State Power Authority would pay the United States the sum of $93,375,000, which is the estimated cost of that portion of the project works chargeable to the United States share of the power in the International Rapids Section. In return, the New York State Power Authority would be given the right to occupy and operate the United States powerhouse and distribute and sell the energy. The River

and Harbor Bill, H. R. 5993, mentioned in paragraph 9c, also contained an item which authorized the President to negotiate the aforementioned arrangement with the New York State Power Authority.

10. THE "238-242" CONTROLLED SINGLE STAGE PROJECT.- a. Paragraph 1 of Article I of the agreement which was signed by the representatives of both Governments on March 19, 1941, provides for the establishment of a Great Lakes - St. Lawrence Basin Commission and outlines its duties. Among other duties are the following from paragraph 1(a) of Article I.

> "To prepare and to recommend plans and specifications for the construction of works in the International Rapids Section in accordance with and containing the features described in the Annex attached to and made part of this Agreement, with such modifications as may be agreed upon by the Governments."

The annex to the agreement, which is quoted below, gives the general outline of the Controlled Single Stage Project (238-242) for development of the International Rapids Section of the St. Lawrence River, which by this time had been accepted by the representatives of both Governments as the best and most economical plan. It will be referred to hereafter in the report as the "Original 238-242 Plan."

"ANNEX

CONTROLLED SINGLE STAGE PROJECT (238-242) FOR WORKS

IN THE INTERNATIONAL RAPIDS SECTION

....

"The main features of the Controlled Single Stage Project (238-242), described in detail with cost estimates in the report of the Temporary Great Lakes - St. Lawrence Basin Committees dated January 3, 1941, are as follows:

"(1) A control dam in the vicinity of Iroquois Point.

"(2) A dam in the Long Sault Rapids at the head of Barnhart Island and two powerhouses, one on either side of the International boundary, at the foot of Barnhart Island.

"(3) A side canal, with one lock on the United States mainland to carry navigation around the control dam and a side canal, with one guard gate and two locks, on the United States mainland south of Barnhart Island to carry navigation from above the main Long Sault Dam to the river south of Cornwall Island. All locks to provide 30-foot depth of water on the mitre sills and to be of the general dimensions of those of the Welland Ship Canal. All navigation channels to be excavated to 27-foot depth.

"(4) Dykes, where necessary, on the United States and Canadian sides of the International boundary, to retain the pool level above the Long Sault Dam.

"(5) Channel enlargement from the head of Galop Island to below Lotus Island designed to give a maximum velocity in the navigation channel south of Galop Island not exceeding four feet per second at any time.

"(6) Channel enlargement between Lotus Island and the control dam and from above Point Three Points to below Ogden Island designed to give a maximum mean velocity in any cross-section not exceeding two and one-quarter feet per second with the flow and at the stage to be permitted on the 1st of January of any year, under regulation of outflow and levels of Lake Ontario.

"(7) The necessary railroad and highway modifications on either side of the international boundary.

"(8) The necessary works to permit the continuance of 14-foot navigation on the Canadian side around the control dam and from the pool above the Long Sault Dam to connect with the existing Cornwall Canal.

"(9) The rehabilitation of the towns of Iroquois and Morrisburg, Ontario.

"All the works in the pool below the control dam shall be

designed to provide for full Lake Ontario level but initially the pool shall be operated at maximum elevation 238.0."

b. The principal features of this plan are shown on Plate No. M-II bound herein, which indicates the status of the plans for the proposed work when the St. Lawrence River District began operations late in 1940. The various features of the improvements have since been studied by the St. Lawrence River District much more extensively than was heretofore possible; a large amount of additional information has been obtained, including subsurface explorations and the opinions of numerous consultants. As a result, it appears that certain changes in the proposed works will be advantageous. See Plates Nos. M-I and M-II. The major suggested changes are:

(1) Relocation of the Long Sault Dam to a point approximately 1,000 feet downstream.

(2) Realignment of the powerhouse by shifting the northerly or Canadian end about 2,500 feet downstream.

(3) Realignment of the Long Sault Navigation Canal.

(4) Realignment of navigation channels between Morrisburg, Ontario and Chimney Point.

(5) Necessary changes in channel dimensions in the vicinity of Galop Island to limit the velocity to approximately 4 feet per second.

The factors suggested are discussed more fully in paragraph 35 of Chapter III, which includes a description of an alternate plan for navigation from that proposed in the Original 238-242 Plan. The alternate plan proposes a navigation channel in a cut through the Island instead of enlarging the natural channel south of Galop Island. None of these changes conflict with the outline plan as quoted in paragraph 10a.

c. Paragraph (d) of Article IV of the agreement of March 19, 1941 stipulates:

"During the construction and upon the completion of the works provided for in the International Rapids Section, the flow of water out of Lake Ontario into the St. Lawrence River shall be controlled and the flow of water through the International Section shall be regulated so that the navigable depths of water for shipping in the Harbor of Montreal and throughout the navigable channel of the St. Lawrence River below Montreal, as such depths now exist or may hereafter be increased by dredging or other harbor or channel improvements, shall not be injuriously affected by the construction or operations of such works, and the power developments in the Canadian section of the St. Lawrence River shall not be adversely affected."

The Canadian Department of Transport has studied this problem at great length and has developed a plan designated as "Regulation Method No. 5", which most nearly satisfies all of the requirements pertaining to the situation. The principal requirements follow:

(1) To keep the fluctuations of the levels of Lake Ontario within the range that would have occurred in the past, assuming a continuous diversion of 3,200 second-feet* at Chicago and present outlet conditions.

*The Diversion now authorized by the Supreme Court of the United States is 1,500 second-feet in addition to domestic pumpage. The combined quantity approximates 3,200 second-feet.

(2) To maintain the low water levels of Montreal Harbor.

(3) To maintain without material changes low water flows, during the period December 15 to March 31 in order that the difficulties of winter operation of the power plants may not be aggravated.

(4) To maintain flows during the first half of April no greater than would naturally occur, in order to avoid the danger of aggravating the spring rise during the breakup of the ice below Montreal.

(5) To avoid any material increase in the amount and duration of high river flows during May, in order not to increase or lengthen the period of high water levels in Lake St. Louis during the flood season in the Ottawa River.

(6) To keep the fluctuations in mean monthly discharges within the existing limits.

(7) To hold back the natural excess outflow during the early summer months, in order to raise the levels of Lake Ontario.

(8) To secure the maximum dependable flow throughout the year for power purposes.

d. These general requirements have been carefully considered in the studies by the District Engineer. Under the project plan now proposed, the pools above the dams will continue to act as channels rather than as reservoirs. Fluctuations of the pool levels and manipulation of the crest gates of the dams will serve to change the river slope, thus controlling the discharge from Lake Ontario and permitting the lake to be regulated as a storage reservoir.

e. The data on which Regulation Method No. 5 is based, together with a discussion of the regulation criteria and tabulations of data on Lake Ontario levels, supplies, and outflows, are given in Department of Transport Document No. 2, dated September 1940, and entitled, "Lake Ontario Levels, Outflows, Supplies, and Regulation". A copy of this document is included in Appendix A-2.

11. PREVIOUS DATA AVAILABLE FOR THIS REPORT.- a. General.- Numerous old records including reports of boards, commissions, etc., up to and including the report of the United States Deep Waterways Commission, which was transmitted to the President on January 8, 1897 (House Document No. 192, 54th Congress, 2nd Session), were available. The information from these sources was general in character and contained little specific data relating to the present problem. Since 1897, several other reports were made and useful information was collected and compiled. A description of the principal available data is given below.

b. Reports.-

(1) Report of Board of Engineers on Deep Waterways.- This report (House Document No. 149, 56th Congress, 2nd Session) submitted June 30, 1900, by a Board of Engineers, designated and appointed by the President in conformity with the provisions of the Sundry Civil Act of June 4, 1897, to make "surveys and examinations including estimate of cost of deep waterways and the routes thereof between the Great Lakes and the Atlantic tidewater" contains important data, particularly the results of field surveys which were made along the St. Lawrence River, including precise levels and numerous bench marks established therefrom. These levels were of first order and furnished many dependable reference points.

(2) Wooten-Bowden Report.- This report (Senate Document No. 179, 67th Congress, 2nd Session), of which a brief description is given in Chapter I, Paragraph 8c, was submitted in 1921. It pertains particularly to the St. Lawrence River between Lake Ontario and Montreal.

(3) Report of the Joint Board of Engineers - 1926.- This report (Senate Document No. 183, 69th Congress, 2nd Session), which is described in Chapter I, Paragraph 8f, contains valuable material and was the basis for all subsequent studies of this project. The report was also printed by the Canadian Government as "St. Lawrence Water Way Project - Report of Joint Board of Engineers with Appendices." The Canadian edition contains all appendices. These were not printed in the aforementioned Senate Document No. 183.

(4) Canadian Conference Report.- This report mentioned in Chapter I, Paragraph 8j, presented a Two Stage Plan. It was printed by the Canadian Government on December 30, 1929, as "St. Lawrence Water Way Project - Report of Conference of Canadian Engineers on the International Rapids Section" with appendix and plates.

(5) The Jadwin Board Report.- This report, entitled "Report of the St. Lawrence Power Development Commission" of the State of New York, was submitted to the Governor and the State Legislature on January 15, 1931. In addition to the engineering features briefly

described in Chapter I, Paragraph 8k, appendices were submitted which contain vital facts pertaining to the legal aspects of the problem and to marketing conditions. The report was printed by the State of New York.

(6) Report of Joint Board of Engineers Reconvened - 1932.- This report mentioned in Chapter I, Paragraph 8l, presented a Two Stage Plan. The report was printed by the Canadian Government on April 9, 1932, as "Report of Joint Board of Engineers Reconvened on the International Rapids Section of the St. Lawrence River" with appendix and plates.

c. Maps and Charts.-

(1) United States Lake Survey Maps and Charts.-

(a) A set of 3 sheets, scale 1:10000, dated 1901, showing all soundings taken to that date in the St. Lawrence River between Williamsburg, Ontario, and St. Regis, New York. Soundings by Mr. F. C. Shenehon, Assistant Engineer.

(b) A set of 4 sheets, scale 1:10000, dated 1921, showing topography on the United States side of the St. Lawrence River between Waddington, New York, and Richards Landing, New York. Topography by Mr. B. D. Bell, Junior Engineer.

(c) A set of 10 sheets, numbered 11 to 20, scale 1:10000, dated 1938; a composite map of all soundings to 1938 in the St. Lawrence River between Ogdensburg, New York, and St. Regis, New York. Surveys by Mr. B. D. Bell, Associate Engineer. District File SS-F-530/1-10. (All files of the St. Lawrence River District will be stored in New York District Warehouse at Mill Rook, N.Y.)

(d) In the fall of 1940, the United States Lake Survey completed a new hydrographic survey of the St. Lawrence River from Cape Vincent, New York, to St. Regis, New York. Results of this survey have not been published, but advance copies of several of the sheets were furnished and have been used.

(e) The regularly published charts of the United States Lake Survey, Detroit, Michigan, which pertain to the International Section of the St. Lawrence River. The following tabulation gives the chart numbers, localities and scales of these maps.

Chart No.	Locality	Scale
11	St. Regis, Ont., to Weaver Point, Ont.	1:30000
12	Weaver Point, Ont., to Lalone Island, N.Y.	1:30000
13	Lalone Island, N. Y., to Brooks Point, N.Y.	1:30000
	Inset: Ogdensburg, N.Y., and Prescott, Ont.	1:15000

Chart: No. :	Locality (cont'd)	Scale
15	Holmes Pt. to Deer Island	1:30000
16	Whiskey I. Shoal to Bartlett Pt. Lt.	1:30000
	Insets: Clayton, N.Y.	1:10000
	Alexandria Bay, N.Y.	1:10000
17	Bartlett Point Light, N.Y., and St. Lawrence Island, Ont., to Cape Vincent, N.Y., and Cold Bath Shoal, Ont.	1:30000
	Inset: Cape Vincent, N.Y.	1:10000
18	Cape Vincent, N.Y., and Howe Island, Ont., to Allan Otty Shoal, N.Y., and Ninemile Point Light, Ont.	1:30000

(2) Maps by the United States and Canadian Geological Surveys.- Maps of both sides of the St. Lawrence River prepared by these agencies in the form of the standard quadrangle topographic maps, are listed below:

(a) Standard United States Geological Survey quadrangle sheets covering the entire United States side of the proposed project, scale 1:62500, contour interval 20 feet. The following sheets cover the territory adjacent to the Thousand Islands and International Rapids Sections of the river on the United States side: Moira, Massena, Waddington, Red Mills, Ogdensburg, Brier Hill, Raymond, Alexandria Bay, Grindstone, Clayton, and Cape Vincent. These maps were procured from the Director, United States Geological Survey, Washington, D. C.

(b) Standard Canadian topographic maps covering the entire Canadian side of the proposed project, scale 1:63360, contour interval 25 feet. The following sheets cover the territory adjacent to the Thousand Islands and International Rapids Sections of the river on the Canadian side; Cornwall, Winchester, Morrisburg, Merrickville, Brockville, Mallorytown, Canoque, Westport, and Wolf Island. These maps were procured from the Surveyor General, Department of Mines and Resources, Ottawa, Ontario, Canada.

(3) The Ross Survey Maps.- Maps prepared from a survey completed by the Frontier Corporation in 1907 and revised in 1923, consisting of 103 sheets, showed topographic and property line features including bearings and distances; datum mean sea level; scale 1 inch equals 200 feet; contour interval, 5 feet. The survey covered the river between Ogden Island and Pollys Gut and extended inland for varying distances. The original survey notes, computations, drawings and tracings are on file in the office of the Niagara Hudson Power Company in Buffalo, New York. One set of process tracings was obtained and is on file in District File SS-F-513/0-102.

(4) Other maps.- Maps, including soundings of the St. Lawrence River and adjacent areas from Chimeny Point to Colquhoun Island, in 5 sheets, were prepared and furnished by the Canadian Depart-

ment of Transport. Scale 1 inch equals 1,000 feet, contour interval 5 feet. The originals are on file in the office of th aforementioned agency, at Ottawa, Ontario, File 2136.

d. Controls.- The following maps and information pertaining to the reference points established during previous surveys listed below, were available.

(1) Triangulation Surveys by the U. S. Lake Survey.- A triangulation net covering the St. Lawrence River from Cape Vincent to St. Regis, New York, made about 1872. Descriptions of points in this system and their positions in geographic coordinates, based on the U. S. Standard Datum in 1902, were obtained from the United States Lake Survey Office, Detroit, Michigan. Prints are in District File SS-N-500/3.0.

(2) Triangulation Survey by International Waterways Commission.- A triangulation system established by the International Waterways Commission in 1911 and 1912, along the St. Lawrence River from Cape Vincent to St. Regis, New York. Positions of points in geographic coordinates, based on North American Datum, were published in the "1915 Report of the International Waterways Commission upon the International Boundary between the Dominion of Canada and the United States through the St. Lawrence River and Great Lakes." This report was published by the Canadian Government Printing Bureau, Ottawa, Ontario. A copy is in District File SS-N-500/3A. In 1938 and 1939, Mr. J. G. Hefty of the International Boundary Commission, Washington, D. C., made an inspection and recovery survey of the aforementioned International Waterways Commission triangulation monuments. The report of Mr. Hefty, which is on file in the office of the International Boundary Commission in Washington, D. C., gives the description of the recovered monuments. A photostatic copy of this report is in the District File SS-N-500/3.1, 3.2 and 3.3.

(3) Precise Levels.- A line of precise levels along the United States side of the St. Lawrence River from Cape Vincent to St. Regis, New York, run by the United States Lake Survey in 1898 and 1899. Descriptions of bench marks and elevations (Mean Sea Level Datum, 1912 adjustment) were obtained from the United States Lake Survey Office, Detroit, Michigan. (Lake Survey File 3-1515.) These data are in District File SS-N-500/3.0. A number of these bench marks are described in the United States Geological Survey Bulletin 671, "Spirit Leveling in New York." A rerun of this line of levelswas made in 1941 by Mr. C. B. McKechnie of the United States Lake Survey, during which ties were made to numerous other bench marks and International Boundary Commission reference points. Several new bench marks within the project area, which have been established by this District, were also tied in. The results of the work performed in 1941 are not yet obtainable. Photostatic copies of data pertaining to a line of precise levels run in 1919, on the Canadian side, were furnished by the Department of Transport of Canada, and a copy of Publication No. 57, containing information relating to other Canadian bench marks, were furnished by the Canadian Department of Mines and Resources. These data are in District File SS-N-500/3.5 and 3.6.

e. Hydraulic Data. The following principal hydraulic data were available.

(1) A large amount of published and unpublished data pertaining to the hydrology of the region and to water levels in the Great Lakes and the St. Lawrence River during the past 80 years, are in the offices of the United States Lake Survey at Detroit, Michigan, and the Department of Transport at Ottawa, Canada. Reports of these organizations contain the results of various studies of schemes for regulation of flow through the lakes and the St. Lawrence River, including effects of diversions.

(2) Department of Transport Document No. 2, pertaining to Lake Ontario levels, outflows, supplies, and regulation, including discussions of the regulation criteria and tabulations of hydraulic data used in the development of Regulation Method No. 5, was prepared in September 1940 by the Department of Transport, Ottawa, Ontario. See Appendix A-2.

(3) Records of ice conditions in the St. Lawrence River and results of laboratory tests and studies of ice conditions were made in the past by Canadian authorities. A detailed tabulation of the available hydraulic data is contained under "Hydraulic Channel Studies" in Appendix A-2.

f. Subsurface Explorations.- Prior to October 1940, the Canadian Government, the United States Government, and various private interests, had at various times conducted explorations to determine the nature of overburden and bedrock in the vicinity of proposed structures and at points where excavations will be made for other purposes under the proposed St. Lawrence River Project. These investigations were preliminary in character and were for the purpose of studying the various alternate plans and layouts for the project. The explorations consisted mainly of wash borings through overburden and of core borings in bedrock. The logs of some of the explorations were available and are in the District Files; some of the cores obtained are stored in the New York District Warehouse at Mill Rock, New York. The location of the explorations are shown on the Canadian Department of Transport maps entitled "St. Lawrence Deep Waterway International Rapids Section Controlled Single Stage Project", a copy of which is in District File SF-G-2/71.

12. NEW SURVEYS.- a. Topographic.- Control traverses for topography, structure layout, canal center lines and profiles were run from the triangulation system by transit and tape as needed. Topography was taken by plane table and stadia. The error of closure for the traverses was limited to 1:1500.

(1) Vertical Control.- The vertical control for all new surveys made was on Mean Sea Level Datum, 4th General Adjustment (1912). Where possible, direct ties were made to the precise level line referred to in paragraph 11d(3). Where this was not convenient, third order levels were run from the precise level line and temporary bench marks established as needed. A list of all bench marks is shown under

"Horizontal and Vertical Control Data" in Appendix A-2 and their locations are shown on Drawing SS-R-505/1 in Appendix A-1.

(2) Horizontal Control.- A check of the triangulation system of the International Waterways Commission referred to in paragraph 11d(2) showed that most of the monuments were still in place. It was decided to use this control system and tie all surveys to it. The first problem was to transfer the control points from geographic coordinates to the Transverse Mercator coordinates (East Zone) for the State of New York, which had been designated as the basis of coordinates for this project. This was done by the method outlined in "Special Publication No. 193 - Manual of Plane-Coordinates Computations" as published by the United States Coast and Geodetic Survey. The maps of the Ross Survey referred to in paragraph 11c(3) are plotted on an arbitrary plane coordinate system. In order to use this survey, it was tied in to the Transverse Mercator coordinates by making field ties from Ross triangulation stations to International Waterways Commission triangulation stations. An equation was then computed between the Ross coordinates and the Transverse Mercator coordinates, and the latter system superimposed on the Ross Maps. Computations for the above conversions are in District File SS-N-500/3.0.

(3) Surveys During Period 1940 to 1942.- The following surveys were carried out by the St. Lawrence River District between November 1940 and March 1942:

Description of Survey	No. of sheets	Scale	District File No.
Topographic. U.S. side from Waddington to Chimney Point, 1 mile inland.	9 and index	1" = 500'	SS-0-511/0; GS-1-511/1-6; OS-1-511/7-8; WS-1-511/10.
Topographic. U.S. side from Coles Creek to Waddington, 2 miles inland.	4	1" = 500'	WS-1-511/9; WS-1-511/11-13.
Profiles. Proposed Rockway Point Canal on center line and 221-ft. offsets.	7	Ver. 1" = 10' Hor. 1" = 100'	QD-1-190/5-9; QL-1-2/4-5
Profile. Proposed road diversion, Waddington to Coles Creek	5	Ver. 1" = 10' Hor. 1" = 200'	WEH-1-550/1-5.
Topographic. Abutment areas of Long Sault Dam site.	1	1" = 200'	BD-1-513/1
Topographic. Area adjacent to Grass River from highway bridge at Aluminum Plant, Massena, to point 8,000 feet east.	2	1" = 200'	MRR-1-513/1-2
Profiles and cross sections. Street and sewer layout of proposed Seaway Village.	12	Pl. 1" = 200' Ver. 1" = 10' Hor. 1" = 200'	MV-1-550/1-11; MV-1-502/1.
Topographic. Massena Airport, including cross sections and profiles of drainage to Grass River.	3	Pl. 1" = 200' (Ver. 1" = 5' (Hor. 1" = 5' (Ver. 1" = 10' (Hor. 1" = 200'	MA-1-513/1; MA-1-550/1; MA-1-551/1-2.
Topographic. Proposed relocation, N.Y. and and Ottawa R.R. via Grass River Lock	3	1" = 200'	MRR-1-551/1-3
Topographic, N.Y. and Ottawa R.R. across Cornwall Island	2	1" = 100'	CRY-1-513/1-2

(cont'd)

Description of Survey	No. of sheets	Scale	District File No.
(cont'd)			
Profile. Proposed N.Y. and Ottawa R.R. bridge site across Pollys Gut.	1	Ver. 1" = 20' Hor. 1" = 100'	MRR-1-550/2
Profiles. Proposed Long Sault Canal on center line and 221-ft. offsets.	16	Ver. 1" = 10' Hor. 1" = 100'	MC-1-10/8-23
Topographic. Canadian side, from Johnstown to Morrisburg, 1000 feet to 1 mile inland.	8	1" = 500'	SS-0-550/50; GS-1-511/51-52; QS-1-511/53-57; WS-1-511/58.
Topographic. Abutment areas at Iroquois Dam site	1	1" = 200'	QD-1-513/2
Cross section. Cornwall Canal Dike at Lock 21.	11	Pl. 1" = 500' Ver. 1" = 10' Hor. 1" = 40'	BC-10-551/0-10
Topographic. Relocation of Cornwall Canal between Locks 19 and 20, 1/2 mile inland.	2	1" = 200'	BS-1-513/1-2

All tracings, original maps, computations, and field notes for these surveys are in the District Files.

b. Aerial.- Aerial photographs of the St. Lawrence River and adjacent areas from Ogdensburg, New York, to the upper end of Lake St. Francis were made by the United States Army Air Corps in May 1941. Mosaics were made from these photographs by the Engineer Reproduction Plant, Army War College, Washington, D. C. One set of 13 mosaics and 1 set of contact prints are in District Files SS-K-1/1 to 1/13. These photographs have been classified as "RESTRICTED" because they show the location of essential manufacturing projects and other details of strategic importance; their distribution has been limited to responsible persons having an official connection with the proposed St. Lawrence River Project.

c. Hydrographic.- The District forces made soundings in the St. Lawrence River from Chimney Point to Point Rockway in the form of profiles. These profiles were run on the center line of the proposed channel and on the 221-foot offsets on each side of the center line.

floats were set on line by survey crews and soundings were made between floats. A Johnson type sounding machine was used, mounted on the launch "Seaway." Soundings were taken at 10-second intervals and located by instrument every minute. They were plotted on a scale 1 inch equals 200 feet. Approximate surface velocities in miles per hour of the St. Lawrence River were measured between Ogdensburg, New York, and Cornwall, Ontario. This was accomplished by calibrating the tachometers on the launch "Seaway" over a measured course in quiet water. The results were plotted on a graph to show motor revolutions per minute, as ordinates, and miles per hour as abscissas. The launch was then spotted at localities where velocities were desired, and throttled down to the point where the motors held the boat stationary against the current. The graph then gave the velocity of the water in miles per hour corresponding to the revolutions per minute read on the tachometers.

13. PERMANENT MONUMENTS AND BENCH MARKS.- a. Horizontal Control.- Tabulations under "Horizontal and Vertical Control Data" in Appendix A-2 give the description and coordinates of all horizontal control monuments used by this District. The locations of these monuments are shown on Drawing SS-R-500/1 in Appendix A-1. The monuments are those of the United States Deep Waterways Commission, the International Boundary Commission, the International Waterways Commission, the United States Lake Survey, and those set by this District as base line control for proposed structures and property line work. The coordinates shown are the geographic coordinates based on North American Datum and the Transverse Mercator coordinates, east zone, for the State of New York.

b. Vertical Control.- The vertical control bench marks used are those of the United States Deep Waterways Survey of 1898, the United States Lake Survey triangulation monuments, the International Boundary Commission reference monuments and the International Waterways Commission triangulation monuments upon which this District established elevations, the Geodetic Survey of Canada, and those established by this District. All elevations are based on Mean Sea Level Datum, 4th General Adjustment (1912). Complete descriptions of these bench marks are given under "Horizontal and Vertical Control Data" in Appendix A-2, and their locations are shown on Drawing SS-R-505/1 in Appendix A-1.

14. NEW EXPLORATIONS.- a. General.- Beginning in October 1940 exploration work was conducted by the St. Lawrence River District, Massena, New York, at sites of proposed channels, cuts and structures to determine more fully the nature and condition of the overburden and bedrock, for guidance in designing and planning the project works. Explorations have also been conducted to locate suitable sources of materials for use as concrete aggregate (see paragraph 16), highway embankments, filter and backing purposes and for the construction of earth dikes. These operations have consisted of extensive geological reconnaissance; drilling in both overburden and bedrock; the determination of bedrock elevations by seismic methods; the excavation of test pits and test trenches; the drilling of auger holes, and probing with a Highmark probing machine and with manually driven rods. Complete reports of all explorations are in the District File SF-G-2/1.00 to 7.3. The explorations conducted for each proposed structure or phase of the project are

discussed in detail in the respective analysis of design or in special reports which are included in the Appendices. The Folio of Subsurface Explorations, which constitutes Appendix B-1 of this report, shows the location and coordinates of all points or areas where explorations have been conducted. Included in this Appendix, are records indicating the character of material at various depths for all drill holes, test pits and probings, and auger holes having numbers greater than T-1500. Auger holes having numbers less than T-1500 are located at widely scattered points, and the records of some of these holes are not included in the Appendix.

b. Geological Reconnaissance.- Field trips along roads, cross country, and waterways, were conducted throughout the valley, to locate superficial features and gather other information which would aid in planning the exploration program and in the interpretation of the geological conditions of the region. Extensive examination of rock outcrops and existing quarries was made in New York and Canada to locate suitable sources of material for concrete aggregates, rip-rap or rock fill, sand and gravel suitable for filter and backing purposes, as well as material for highway embankments (see paragraph 16b).

c. Contract Drilling.- Extensive drilling operations were carried out under contract by Sprague and Henwood, Inc., of Scranton, Pennsylvania. The following work was accomplished by methods described in the three following sub-paragraphs.

Holes in Bedrock........................	10,500 lineal feet
Holes in Overburden, 3½-inch casing......	17,400 lineal feet
Holes in Overburden, 2½-inch casing......	5,900 lineal feet
Holes in Clay deposits, 6-inch casing....	750 lineal feet

(1) Holes for Investigating both Overburden and Bedrock.- Holes for this purpose were put down with diamond drilling equipment using 3½-inch casings in the overburden and 2-1/8-inch core bits in the bedrock, except a few holes which were finished with a 1-3/8-inch core bit after caving or other difficulties prevented the further use of the 2-1/8-inch bit. Dry soil samples usually taken at 5-foot intervals or at changes in material were obtained in most of the holes. As a rule, holes drilled to determine the elevation of bedrock were extended 20 feet into the rock to verify the fact that bedrock had actually been reached and to obtain rock cores for visual examination. At the proposed sites of large concrete structures, where the character and condition of the bedrock would be of more importance, some drill holes were carried 100 feet into the rock. Special conditions encountered, such as brecciated zones and gypsum deposits, were investigated by drilling deeper holes, some of which extended 200 feet into the bedrock. All rock cores and soil samples obtained are stored in the New York District Warehouse at Mill Rock, New York.

(2) Holes in Overburden Only.- Holes for investigation of the overburden only were drilled using either 2½-inch or 3½-inch casings. All holes of this type with numbers greater than D-1500 were

drilled using $2\frac{1}{2}$-inch casing. Dry samples were taken by means of sampling tubes $1\frac{1}{2}$ inches and 2 inches in diameter. The samples were usually taken at 5-foot intervals or at changes in material, and wash boring methods were permitted between samples.

(3) Holes for Obtaining Undisturbed Samples.- Holes were drilled using 6-inch casing at certain points along the Long Sault Canal and adjacent dikes, and at the site of the Point Rockway Lock and new Cornwall Canal Dike for the purpose of obtaining undisturbed samples of marine clay deposits. During the initial stages of this work, a Massachusetts Institute of Technology sampler spoon was used, but due to the characteristics of the soft marine clay, many of the samples were lost. To overcome this difficulty, a sampling spoon equipped with special features for retaining the samples, furnished by Sprague and Henwood, Inc., was used and somewhat better results were obtained. A detailed description of the difficulties encountered during these operations and of the special spoon used is included in the appendices relating to the pertinent structures.

d. Exploration by Government Forces.- Explorations were conducted by Government forces at many sites for the purpose of obtaining information regarding the foundations; for locating deposits of suitable material for borrow; and for determining the location and extent of soft materials along the alignment of canals. The work included:

(1) Test Pits.- Numerous test pits were excavated where detailed information was desired, particularly near the surface. The pits, which were not sheathed, were excavated to a depth of approximately 6 feet and where possible, were extended by auger borings. Bag and jar samples were taken in each stratum of material encountered. Two deep test pits, T-1000P located on the initial alignment of the Long Sault Canal and T-1001P located at the proposed site of Dike No.4 of the Long Sault Canal, were excavated to obtain detailed information and undisturbed samples of soft marine clay, which had been found in those localities. Test pits with numbers less than T-1500 were used to explore foundation conditions and to locate deposits of suitable material for borrow. A total of 290 test pits were excavated.

(2) Auger Holes.- Many auger holes were drilled as deep as possible, using a 5-inch hand auger, and then were extended by means of probing. Bag samples of the overburden were taken. A total of 669 auger holes were drilled. Auger holes having numbers less than T-1500 were used to explore foundation conditions and to locate deposits of suitable material for borrow.

(3) Probings.- Two types of probings were used to determine the condition of overburden along the alignment of the canals and at the dike sites. Hand probings, using 3/4-inch rods and a 14-pound sledge hammer, were used to extend auger holes and to supplement the test pits, particularly along the alignment of the Long Sault Canal. The notation "P" was used for holes made by hand probing methods. A High-

mark probing machine was used to determine the depth to firm material at localities of channel excavation and other cuts and at some dike sites. These holes were designated "PH". The Highmark machine drives a $1\frac{1}{4}$-inch probing pipe using a closed, removable tip or point which can be retracted without pulling the casing when samples are desired. To obtain samples in clay, an open end pipe 3/8-inch inside diameter, was forced into the soil below the probing pipe. In sandy materials, a pipe, 3/8-inch inside diameter, having a closed end and a slot in the wall approximately two inches from the end of the pipe was used. The samples obtained with this device were either washed through the slot or scraped through as the sampler was moved up and down. The probing pipe was driven with a hammer weighing 163 pounds and dropping approximately 15 inches at an average rate of 50 blows per minute. A field log was kept of each hole which recorded the rates of penetration as well as the description of samples obtained. A total of 731 holes, 21,400 lineal feet, was probed with this machine.

e. Exploration by Seismic Methods.- Subsurface conditions were believed to be such that the seismic method of investigation could be successfully used, that the contact surface between the bedrock and the overburden could be determined with a fair degree of accuracy, and that some success in the classification of the overburden might be achieved. A program of seismic investigations was therefore inaugurated. The results of these investigations were used as a guide in planning a drilling program to obtain more detailed information. Only a few seismic determinations were made at sites where sufficient data for laying out the drilling program were available. In general, the seismic method was used to obtain additional information between the drill holes or in the vicinity. The drilling program was thus reduced to a minimum. The seismic method and instruments used were those developed by Mr. E. R. Shepard, Senior Physicist, Office of the Chief of Engineers, United States Army. They are described in the article entitled, "The Seismic Method of Exploration Applied to Construction Projects" by E. R. Shepard, published in the October,1939 issue of "The Military Engineer." Special subaqueous seismic investigations to obtain elevations of the surface of bedrock were conducted at some points along the proposed channels where drilling would be dangerous or very costly. The conventional seismic methods used on land were adapted to the requirements of subaqueous work by developing special apparatus and technique. The lines were laid out and fired in the same manner as in land operations, but the detectors were mounted in waterproof cartridges held on the river bottom by special equipment. Subaqueous investigations were also made in swift water at the Long Sault Dam site by locating the oscillograph on land and firing single shots in the channel. A report describing the seismic investigations is included as Appendix B-2. The results of most of the lines shot on land and in quiet water are believed to be within the usual limits of accuracy of seismic work. The results from some lines, however, were unsatisfactory, probably due to the effect of frost in the ground and to the fact that some of the lines were located in areas where thick blankets of fill had been deposited. These unsatisfactory lines are not shown on the drawings in the folio of sub-surface exploration, Appendix B-1. Results were also unsatisfactory in one area of the Point Rockway Canal, probably due to unusual soil and rock condition. A total of 392 satisfactory lines

were fired, excluding the work in the swift water at the Long Sault Dam site.

f. Additional Exploration Required.- Explorations carried out by this District have been confined chiefly to the sites of the Iroquois Dam, Point Rockway Canal, Long Sault Canal, including its locks and dikes, Massena Canal Intake Works, the Long Sault Dam, the Barnhart Island Powerhouse, including the forebay dike, and the new Cornwall Canal. Before commencing construction, some additional holes at these sites should be drilled in order to obtain more detailed information at certain points and to verify assumptions made in the designs. The quantity of such work required at the site of each feature is discussed in the analysis of design for that feature in the accompanying appendices. At the sites of other structures and along the proposed cuts in channels, the exploration work has been limited, and considerable additional exploration work should be performed before completing the designs and compiling estimates of cost.

g. Laboratory and Field Tests on Soils and Bedrock.- A soils laboratory was organized for testing the samples obtained during the exploration work. The laboratory was equipped for making routine tests only as the extent and nature of the studies to be made were not originally known. As the investigations progressed and it became apparent that before adequate designs could be made it would be necessary to determine the stress-strain characteristics of the marine clays and silts existing as overburden deposits throughout the project area, arrangements were made for supplementary tests at the Binghamton District Soils Laboratory at Ithaca, New York. The undisturbed samples of clay obtained from 6-inch holes were tested. The methods used for all routine and special tests are described in the analyses of design for the various features, in the accompanying appendices.

15. LANDS AND EASEMENTS.- a. General.- Article X (c) of the International Agreement signed March 19, 1941, states, "Each government will assume the responsibility for and the expense involved in the acquisition of any lands or interests in land of its own territory which may be necessary to give effect to the provisions of this Agreement." Accordingly, preliminary investigations for acquisition of lands and easements required for the project were limited to those areas situated within the boundaries of the United States. No investigations were made of Canadian lands. The intent of this work was, in general, to secure sufficient data concerning those properties which will be required during the first year or two of construction so as to negotiate for the purchase of the properties or, if necessary, to initiate condemnation proceedings immediately upon authorization of the proposed project.

b. Work Done and Methods Employed.- The preliminary property investigations may be divided into four separate phases of work, as follows:

(1) Preliminary searching and mapping.
(2) Surveys.
(3) Appraisals.
(4) Abstracts of title.

Work was started on those lands which will be required for first priority construction, and as time permitted was followed by work in the areas of lower priority.

c. Preliminary Searching.- All available information relative to property boundaries and ownership was obtained by interviews with owners or residents of the properties, and was recorded on interview sheets. These sheets were transmitted to searchers in the County Clerk's Office, who secured from the record a legal description of the property. From the information obtained, base maps showing the approximate boundaries of each tract of land were prepared. The work included use of a number of old maps showing the original patents and subdivisions of the land. These maps will be of considerable assistance and value in reviewing titles. Interview sheets and deed descriptions for each individual parcel of land are contained in District File BLA-L-400/32 to WLA-P-400/W47. The area covered during this work is indicated on Drawing SLA-R-1/1 in Appendix A-1.

d. Surveys.- Surveys were made for the purpose of determining boundary lines, improvements on the land, and other pertinent data. Most of the deed descriptions covering properties in the area were too general to be used as a basis for the accurate determination of property lines. Existing fence lines, roads or other physical characteristics, which had been accepted as property boundaries over a period of years were therefore surveyed and used. Partial takings of many tracts are involved in the section between the Village of Waddington, New York, and Chimney Point. Taking lines were surveyed and established throughout most of this area. The taking line for the pool was assumed at elevation 250.0 feet mean sea level. It was unnecessary to make complete land surveys for that portion of the project area extending 10 miles east of the Massena Power Canal since this area was included with sufficient accuracy in the Ross Survey (paragraph 11c(3). Certain property lines shown on the Ross Survey were checked in the field to establish the accuracy of this survey. The only additional work necessary in this area was to survey the properties which had been subdivided since the Ross Survey in 1907. The Ross Survey has been used as a basis for numerous conveyances in this area over a period of years and consequently has some value as a basic document for land work. A complete set of the Ross Maps, together with necessary surveyor's certificate and other affidavits are in District File SLA-F-1/P90. It is anticipated that this survey will be placed on record in the County Clerk's Office of St. Lawrence County when work on the project is started and will then be used as a basis for many of the legal descriptions of property prepared by this office. From the survey data secured, individual plat maps and legal descriptions were prepared for each parcel of land. Descriptions are referenced in most instances to existing monuments of the International Boundary Commission and International Waterway Commission. In a few instances, permanent monuments were established by this office for property reference ties. The area covered by field surveys, including those areas for which the Ross Survey was adopted, is indicated on Drawing SLA-R-1/2 in Appendix A-1. Areas for which plat maps have been drawn and legal descriptions written are indicated on Drawing SLA-R-1/3

in the same appendix. A complete set of tracings with all property surveys plotted thereon are in District File BLA-L-400/32 to WLA-P-400/W47. Legal descriptions and plat maps for each parcel of land are in File BLA-L-400/32 to WLA-P-400/W47.

e. Appraisals.- Detailed property appraisals were made of 228 parcels of land, by a Department appraiser and by qualified local appraisers employed by this office who worked independently. Two or more appraisals were secured for the same property in many instances. The purpose of this procedure was to secure sufficient independent appraisals on representative properties in each locality to definitely establish the valuation and adequacy of the appraisals for that particular area. The area east of the Massena Power Canal, including Barnhart and Long Sault Islands, contains 175 parcels of land, and 275 independent appraisals were made in this area. Drawing SLA-R-1/4 in Appendix A-1 shows the area covered by appraisals. Individual appraisal reports are in District File BLA-L-400/32 to WLA-P-400/W47.

f. Abstracts of Title.- Abstracts of title, which will be required upon authorization of the proposed project, were prepared for as many properties as possible. A total of 32 abstracts were made by this office. In addition, the field interviewers obtained, whenever possible, abstracts in the possession of property owners. Photostatic copies of these abstracts were made and placed in the files. In some instances, these abstracts can be readily completed while, in other instances, the abstracts secured from property owners will prove of little value. A total of 62 completed or partially completed abstracts are in the District Files. Abstracting was done by two attorneys who worked intermittently. Because sufficient funds were not available, it was not considered economical or practicable to establish an elaborate organization for abstracting titles to all property required. It was considered that upon authorization of the proposed project, abstracts would, in most instances, be secured by contract.

g. Summary.- Preliminary searching of titles for all lands on the American side is approximately 92 per cent complete; surveys 60 per cent complete; preparation of plat maps and legal descriptions 40 per cent complete; and appraisals 7 per cent complete. It is estimated that a force of 12 office employees and one survey party could complete the preliminary work, excluding appraisals and abstracts of title, within a period of 4 months. A force of 4 appraisers could complete remaining property appraisals within a period of 6 months. The status of preliminary investigations for each individual parcel of land is shown in the tabulation under "Land Acquisition, Status of Preliminary Investigations" in Appendix A-2. The status of these investigations for various sections of the proposed project area is as follows:

(1) The area between Massena Point and the Massena Power Canal, Mile 107.5 to Mile 99 (see Plate M-1, bound herein), including Long Sault and Barnhart Islands is complete with respect to searching, surveys, plat maps and legal descriptions and appraisals. A number of abstracts of title have also been prepared for properties in this area. Additional work necessary will be to secure, preferably by contract,

abstracts of title for the remaining parcels of land.

(2) From the Massena Power Canal to the easterly limits of the Village of Waddington, Mile 99 to Mile 83.5, preliminary searching has been completed and deed descriptions secured for approximately 73 per cent of the properties. In addition, surveys, plat maps and legal descriptions have been completed for properties on Croil Island. The major portion of the land in this reach will be acquired for flowage purposes only. Early acquisition of this land is not required since the construction work, including levees and highway relocations, are of low priority.

(3) Between the Village of Waddington and the proposed Iroquois Dam, Mile 84.5 to Mile 77.5, a considerable amount of work has been accomplished. Field surveys have been completed for the entire area, with the exception of the Village of Waddington, where a limited amount of additional survey work is necessary. Appraisals have been secured covering the area from Point Rockway to Leishmans Point, which is required for construction of the Iroquois Dam, Point Rockway Canal and for the dredging operations.

(4) From Iroquois Dam to the westerly limits of the proposed project at Chimney Point, Mile 77.5 to Mile 68, field surveys have been completed. Appraisals have been completed for the Sparrowhawk Point Construction Area. Plat maps and legal descriptions have not been prepared for the mainland area west of Sparrowhawk Point because taking lines were not established. Considerable land for spoil areas must be acquired in this reach.

16. CONCRETE AGGREGATE.- a. General.- Investigations and studies pertaining to sources, quality tests, and special applications of materials were undertaken. Initially, tentative specifications for materials were set up based on available information and current standards, followed by investigations with a view to selection of more desirable materials, or methods which could be substituted. It is estimated that the principal structures of the proposed St. Lawrence River project will contain approximately 4,500,000 cubic yards of concrete, which will require 2,500,000 tons of sand and 5,500,000 tons of coarse aggregate. A tabulation given in paragraph 1-03 of the concrete aggregate specifications in the supply contract, Appendix C, shows the breakdown of the quantities and the tonnage of both fine and coarse aggregates required for each major feature of construction. The dams, powerhouses, lock walls and other important features, should be constructed for long life notwithstanding their exposure to severe climatic conditions. Therefore, materials of best quality are required. Factors which determined the scope of the aggregate investigations were the quantity of material required, the high standard of quality necessary to produce durable concrete, and the lack of adequate service records for most of the materials available within the district. Explorations for locating sources of supply for these materials were started in January 1941, and continued until December 1941. The geology of the overburden and bedrock in the region is given in paragraph 6. In addition, significant geologic, mineralogic, and economic data pertaining

to major individual deposits of material which may be suitable for concrete aggregate are given under "Concrete Aggregate Investigation" in Appendix C. Brief discussions of the status of the work and the significance of the information obtained, together with recommendations regarding further disposition of the problems, follow.

b. Field Reconnaissance.- The materials survey was started by inquiries regarding aggregate deposits from neighboring United States Engineer Districts, state and county highway engineers, the Canadian Department of Public Works, and many commercial agencies in New York and Canada. The data obtained were supplemented by interviews, personal investigations and inspections of all aggregate deposits reported by the aforementioned agencies. Field reconnaissance was also made in the region bordering the St. Lawrence River within the project area. The explorations were extended to cover Canadian sources from Kingston and Perth, Ontario, on the west to Montreal and Joliette, Quebec, on the east; and in New York State, the explorations were carried out as far as Oswego and Boonville on the southwest and Saranac Lake, Lyon Mountain and Owls Head on the southeast. The sand and gravel deposits and rock outcrops located in the United States and in Canada, are shown on Quadrangle maps S-A-3/5 to S-A-3/36 under "Concrete Aggregate Investigation" in Appendix C. Drawing S-A-3/1, showing drilling and seismic explorations for quarry sites at Mille Roches, Ontario; Knapp Station, New York; and on the St. Regis Indian Reservation, and Drawing S-A-3/2, showing test pits and auger borings in a sand and gravel deposit at Owls Head, New York, are included in Appendix B-1. Samples were taken of all deposits which appeared suitable for concrete aggregates and, where warranted, the samples were submitted to the U.S.Engineer Central Concrete Laboratory at West Point, New York, for testing. Field inspection reports, giving pertinent data regarding each of the deposits investigated in the United States and in Canada, are in the District Files SCM-G-3/1 and 3/2. Typical examples of the field inspection reports are given under "Concrete Aggregate Investigation" in Appendix C. A copy of a memorandum to G. A. Lindsay, Chairman, Canadian Temporary Great Lakes - St. Lawrence Basin Committee, covering some of the possible sources of concrete aggregate in Canada, investigated by Mr. E. Viens and Miss A. E. Wilson of the Department of Public Works and the Geologic Survey is included under "Concrete Aggregate Investigation" in Appendix C. The material in deposits investigated was first given a visual examination to determine the gradation of the particles; the presence or absence of silt, shale, disintegrated stone, fossils, and shells; the cementing medium; shape of particles; and the probable origin of the material. If the material appeared favorable, an estimate of probable quantities was prepared based on rough measurements and geological conditions. Inquiries regarding former production and uses of the material were made of local parties and the transportation facilities and possibilities for processing were considered. Several deposits were found which contained sufficient material to warrant detailed investigations. These deposits consisted of four distinct types: (1) natural sand and gravel, (2) dolomite rock, (3) limestone rock, and (4) iron ore tailings. A brief resume of the results of the field explorations for each deposit and its location is given under "Concrete Aggregate Investigation" in Appendix C. The results of standard laboratory tests of fine and coarse

materials tested at the Central Concrete Laboratory, West Point, New York, are included in Tables S-A-3/3 and S-A-3/4 under "Concrete Aggregate Investigation" in Appendix C. The investigations made have covered nearly all of the promising deposits within this territory and very little further search is deemed necessary.

c. Sources of Acceptable Concrete Aggregate.- The most favorable sources, as obtained from the investigation, for concrete aggregate, which meet the requirements of current specifications, are summarized in the following table:

TABLE 1 - SOURCES OF CONCRETE AGGREGATE

No.	Type of Material	Location	Approximate Quantity of Material Available	Transportation Available
1	Dolomite*	2 miles north of Norwood, N.Y., Pit No. 8	Unlimited	15 miles by N.Y.C.R.R. to Massena, N.Y.
2	Dolomite*	Near Knapp Station N.Y., Pit No. 30	Unlimited	10 miles by N.Y.C.R.R. to Massena, N.Y.
3	Dolomite*	In Village of Ogdensburg, N.Y., Pit No. 904	Unlimited	57 miles by N.Y.C.R.R. to Massena, N.Y. Approximately 45 miles by barge.
4	Dolomite*	1½ miles northwest of Helena, N.Y., Pit No. 108	Unlimited	10 miles by Grand Trunk R.R. to Massena, N. Y. 6 miles by N.Y.C.R.R. to Cornwall Junction, Canada.
5	Dolomite*	Point Rockway Canal Site, Pit No. 805	Sufficient for works in vicinity of Pt. Rockway, N.Y.	At site
6	Limestone**	1 mile north of Mille Roches, Ontario	Unlimited	5 miles by Canadian National R.R. to Cornwall Junction.
7	Natural Sand	10 miles northeast of Joliette, Que.	Unlimited	125 miles by Canadian National R.R. to Cornwall, Ont.
8	Natural Sand and	In Village of Owls Head,	4,000,000 cu.yds. of	61 miles by N.Y.C.R.R. and Rutland R.R. to Massena, N.Y.

TABLE 1 - SOURCES OF CONCRETE AGGREGATE
(cont'd)

	Gravel	N.Y., Pit No. 1501	sand. 2,000,000 cu.yds.of gravel	
9	Natural Sand	1½ miles south of Crogham, N.Y., Pit No. 5201	Unlimited	102 miles by N.Y.C.R.R. to Massena, N.Y.
10	Natural Sand	1½ miles south of Boonville, N.Y., Pit. No. 7700	Unlimited	125 miles by N.Y.C.R.R. to Massena, N.Y.

*Source for both fine and coarse crushed aggregate.
**Source for coarse aggregate only.

Other sources of possible merit for concrete aggregates are shown in Table 2. Investigations of these deposits have not been completed because of the variable nature of the deposit, unfavorable location, inaccessibility, and the similarity of the material to other materials which had been included in special studies. Future developments influencing these factors might justify further consideration and subsequent detailed investigation.

TABLE 2

OTHER POSSIBLE SOURCES OF CONCRETE AGGREGATES

No.	Type of Material	Location	Approximate Quantity of Material Available	Transportation Available
1	Dolomite	Railroad quarry in Prescott, Ont.	Unlimited	44 miles by Canadian National R.R. to Cornwall Junction, Ont.
2	Dolomite	Windmill Point, Ont.	Unlimited	44 miles by Canadian National R.R. to Cornwall Junction, Ont.
3	Limestone	3 miles north of Cornwall, Ont	Unlimited	No railroad facilities.
4	Natural Sand	8 miles northeast of Oka, Que.	1,000,000 tons	Approximately 70 miles by barge to Cornwall, Ont.

TABLE 2
OTHER POSSIBLE SOURCES OF CONCRETE AGGREGATES
(cont'd)

5	Natural Sand	Near Village of St. Felix de Valois, Que.	Unknown but probably large	Approximately 135 miles by rail from Massena, N.Y.
6	Iron ore Tailings	In Village of Lyon Mountain, N.Y., Pit No. 1600	20,000,000 tons of fine aggregate. 500,000 tons of coarse aggregate	85 miles by Delaware & Hudson, N.Y.C., and Rutland R.R. to Massena, N.Y.
7	Natural Sand	3/4 mile west of Village of Santa Clara, N.Y. Pit No. 1401	Sufficient fine aggregate for the St. Lawrence River Project.	36 miles by highway to Massena, N.Y. No railroad facilities
8	Natural Sand	1 mile southwest of Village of Brier Hill, N.Y., Pit No. 900	500,000 cu. yds.	74 miles by N.Y.C.R.R. to Massena, N.Y., or 35 miles by barge to Point Rockway, N.Y.

Materials from other possible sources should be considered and tested when submitted for approval.

d. Method of Purchase.-

(1) In view of the large quantity of aggregates required and the high rate of delivery, it is believed that it will be advantageous to purchase these materials on supply contract for delivery at the site of the work. However, it might be advantageous for contractors to furnish the aggregates at the Point Rockway Canal, Iroquois Dam, and miscellaneous temporary structures. The dolomite rock to be excavated from the Point Rockway Canal is believed to be of satisfactory quality and the quantity will be sufficient to supply aggregates for both the dam and the navigation lock at that locality. The contract form for supplying aggregate, including the detailed requirements and specifications, together with an explanation of the special features of the technical requirements, and details of the invitation for bids and general provisions is given under "Concrete Aggregate Supply Specifications" in Appendix C.

(2) The concrete aggregate specifications were prepared in accordance with the Standard Federal Specifications with minor modifications to meet the special conditions existing at the location of the proposed project. The specifications permit the use of the best

quality aggregates only, and require that they be properly graded from the maximum size in the coarse fraction to No. 200 sieve in the sand fraction. In general, aggregates of 6-inch maximum size are specified for use in massive concrete sections, while aggregates of various sizes up to and including 3-inch and $1\frac{1}{2}$-inch maximum sizes, are specified for those sections where the larger sizes could not be advantageously used.

e. Influence of Aggregate on Durability of Existing Concrete Structures.- Evaluation of the influence of aggregates on the durability of existing concrete structures was an important part of the investigation. Particular attention was given to the resistance to weathering of concrete in hydraulic structures, which contained materials obtained in this region or similar material obtained elsewhere. Several examples of disintegrated concrete were traced to the unsoundness of the coarse aggregates. Reports covering investigations of several structures are in the District File SCM-H-3/4.1. The most important concerned the Prescott Grain Elevator, Prescott, Ontario; the Powerhouse, Aluminum Company of America, Massena, New York; and the Beauharnois Power Project, Beauharnois, Quebec. The results of the investigations at these and other structures outside the area are discussed below.

(1) Prescott Grain Elevator.- The aggregate used in the Prescott elevator was reported to have come from Grenadier Island and to have been used in a "pit-run" condition. Examination of the weathered dolomite, or "mudrock", which constitutes approximately 3.5 per cent by weight of the Grenadier Island gravels and a petrographic analysis of the rock taken from the apex of two small "pop-cuts" in the concrete of the elevator, indicated that the two materials were very similar. The pebbles appeared to be a calcareous mudrock in various degrees of consolidation, which absorbed water very rapidly and disintegrated readily when immersed. The high porosity makes this type of rock very susceptible to failure when subjected to freezing and thawing.

(2) Powerhouse, Aluminum Company of America, Massena, New York.- The original powerhouse was built in 1898 and enlarged during 1912 and 1913. The source of the materials used in the concrete could not be definitely determined as no records were available. However, it is reported that crushed dolomite was used as coarse aggregate in the original powerhouse, and bank run sand and gravel from the vicinity of Potsdam, New York in the enlarged portion. The concrete of the new part is badly disintegrated, obviously due to a high percentage of unsound sedimentary rock in the aggregate; while the concrete in the original structure, in which crushed dolomite was used, appears to be in much better condition.

(3) Beauhornois Power Project, Beauharnois, Quebec.- Construction was started in 1929 and the plant was placed in operation in 1932. Potsdam sandstone was used in the concrete for both fine and coarse aggregate. The rock was supplied from the areas excavated for the powerhouse and tailrace and was crushed near the site of the project. The concrete, inspected in 1941, appeared to be in good condition, which indicates that this type of material is satisfactory for use in concrete.

(4) Other Structures.- Inspections were made of a few large concrete structures located at points outside the area, including Chute-a-Caron Dam at Arvida, Quebec; Norris Dam, Hiwassee Dam, and several other structures located in Tennessee and neighboring states. Considerable information was gathered which shows the effect on the life and quality of the concrete, of special types of aggregates, aggregate gradations, concrete mix design and methods of placing. A memorandum giving complete details of these observations is in the District File SCM-H-3/4.1.

f. Special Tests.- In the preliminary investigations of concrete aggregate, the magnesium sulphate accelerated soundness test was employed to determine the quality of material found in numerous deposits in the vicinity of the proposed St. Lawrence River project. The results of this test are considered indicative only and not a final criterion of durability. Therefore, freezing and thawing tests on concrete specimens containing these materials were made. Three series of freezing and thawing tests were made.

(1) Series A.- Representative materials from four of the larger sources of supply were included in this group of tests. Twenty-four 6" x 6" x 48" concrete columns were made of these materials; twelve for freezing and thawing on exposure racks at Eastport, Maine, and twelve for use as control specimens. Resistance to freezing and thawing was measured by the sonic method and by visual inspection.

(2) Series B.- Materials from three of the sources included in Series A and others from three additional sources were used for this series of tests. Thirty-six $3\frac{1}{2}$" x $4\frac{1}{2}$" x 16" concrete beams were made; eighteen for laboratory freezing and thawing tests and the remainder for control specimens. Resistance to freezing and thawing was evaluated on the basis of sonic modulus and flexural strength tests.

(3) Series C.- The tests in this series were made to determine the relative durability of various natural and manufactured sands when used with dolomite coarse aggregate. Each fine aggregate selected for the tests represented either a large single deposit or a group of deposits. Ten 3-5/8" x $4\frac{1}{2}$" x 18" beams were made for each of nine fine aggregate combinations tested; forty-five were subjected to freezing and thawing tests on exposure racks at Massena, New York, and the remainder used as control specimens. The latter were tested in flexure at 28-day age for comparison with similar tests to be made on the former group, following 60 cycles of freezing and thawing. Detailed descriptions of the procedures and methods, and the tabulation of results are given under "Concrete Aggregate Investigation" in Appendix C. The conclusions derived from these results are given in subparagraph g.

(4) Other Tests.- In addition to the durability tests, special studies were made on aggregates from the aforementioned sources. These included tests for staining, crazing, alkali reactivity, head diffusivity, relative mixture economy, flexural and compressive strength,

bleeding tendencies, and density. The test procedure used and the results obtained are given under "Concrete Aggregate Investigation" in Appendix C. In addition to the aforementioned, the freezing and thawing tests on crushed rock of various sizes to 2 inches maximum, from the Northern Quarries and the Mille Roches Quarries, were subjected to 25 cycles of freezing and thawing in an evacuated-saturated condition. Also 96 dolomite core samples of 2-inch diameter and varying in length from 2.5 to 13 inches, obtained from core holes along the Point Rockway Canal and 59 limestone core samples of similar dimensions, obtained from Mille Roches Quarries, were subjected to 34 cycles of freezing and thawing. The description of the test procedure, weight determinations, photographs of core samples before and after freezing and thawing are in the District File SCM-P-3/1.

g. Conclusions and Recommendations.-

(1) Coarse Aggregate.- Comparison of the results of the exposure tests at Treat Island, Maine, and the laboratory freezing and thawing tests on beams showed that the beams in which natural gravel was used as aggregate were decidedly inferior to those in which crushed stone aggregates were used. The tests gave no indications that any of the three crushed rock coarse aggregates used (dolomite, limestone and Lyon Mountain syenite) had an unfavorable effect on the concrete, or that any one of the three was superior to the others. The accelerated freezing and thawing of saturated samples of the Beekmantown dolomite and the Black River limestone, not confined in concrete, showed both of these materials to be amply resistant to this type of exposure. The test caused no appreciable failure either in the crushed particles or in the drilled cores. Based on information derived from the various tests, field inspections and geological studies, it appears unlikely that any satisfactory natural gravel for use as coarse aggregate for the major features of the project, will be found within economical transportation distance of the proposed project. However, it is recommended that provisions permitting the use of gravel, contingent upon approval after thorough tests, be retained in the specifications. The Black River limestone was found to be satisfactory for use as coarse aggregate. Because of the solubility of the finer sizes of this material, it was not considered acceptable for use as fine aggregate.

(2) Fine Aggregate.- The natural sands found in beaches and bars within 50 miles of the proposed project contain a high percentage of deleterious material. Magnesium sulphate accelerated soundness tests on these sands showed losses greater than the specified limit. Sand from kames and deltas located near Malone, New York, and on Grenadier Island also were found unsatisfactory. Satisfactory natural sand has been found in large deltas located near Lowville, New York, and at Joliette, Quebec. While it has not been proved that the unsoundness of the sand from some of these deposits, as indicated by the magnesium sulphate tests, will seriously affect the durability of concrete in which they are used, it would be unwise to accept them without further investigation. Additional freezing and thawing tests should be made for final decision regarding their suitability. The studies of fine aggregate

consisting of crushed dolomite definitely showed that this material is entirely satisfactory with respect to the strength and durability of the concrete. Substitution of the crushed fine aggregate for natural sand may necessitate the use of some additional cement to produce the required workability. However, the high strength and durability of concrete made with the dolomite fine and coarse aggregate indicate that a larger water content would be permissible, thus reducing the amount of additional cement required. Improvement in particle shape and gradation which may be obtained as the work progresses may increase the workability to such an extent that no additional cement will be required. Iron ore tailings(crushed syenite from Lyon Mountain) appeared from strength and durability tests to be as satisfactory as the crushed dolomite for use as fine aggregate, but the foregoing comments on workability are also applicable to this material. Studies of alkali reactivity of this material and other aggregates included in this investigation, showed no deleterious results. A significant fact brought out by the laboratory studies was that the concrete in which all of the aggregates were of the same type of stone, or mineral, showed higher flexural strength and greater resistance to deterioration by freezing and thawing, than concrete in which mixed aggregates were used. This was true for the columns tested at Treat Island, Maine, in which the Lyon Mountain syenite was used, as well as for all specimens in which cross mixtures of crushed dolomite and limestone fine and coarse aggregates were used. This fact conforms to the theory that uniformity in respect to physical properties, such as thermal coefficient and modulus of elasticity, in structural concrete is a factor which should be considered in the selection of materials. However, the tests which have been made on this subject are very limited and further tests are necessary before definite conclusions are established. Certainly the manufacture of concrete using crushed limestone as coarse aggregate and crushed dolomite as fine aggregate, should not be permitted without extensive additional investigation.

(3) Additional Investigation.- It is recommended that additional tests of various combinations of coarse and fine aggregate as outlined under "Concrete Aggregate Investigation" in Appendix C be made.

17. CEMENT INVESTIGATIONS.- a. Several factors govern the selection of the type of cement for use in mass concrete. The special properties which the cement should possess, in addition to normal requirements, are: (1) low heat generation; (2) high degree of workability in concrete; (3) good water retentiveness; (4) low coefficient of expansion; and (5) a high degree of resistance to weathering. Portland cement made according to Federal Specifications SS-C-206a Moderate-Heat-of-Hardening Cement, has been used in many locks and dams, and, in the majority of cases, has proved to be satisfactory. Nevertheless, it is believed that consideration should be given to new types of cement which have been developed, as, for example, cement treated with Vinsol-resin, which reportedly produces concrete having greater plasticity and workability, less tendency to bleed and greater resistance to freezing and thawing. A limited number of tests on concrete made with Vinsol-resin cement were conducted at West Point, New York, and at Eastport, Maine, including the testing of 6" x 6" x 48" concrete beams by freezing and

thawing, for flexural strength, and for density. In addition, 6" x 12" concrete cylinders were tested for compressive strength and heat diffusibility. The results of these tests are shown under "Concrete Investigation" in Appendix C.

b. Flood walls, drop structures, and airport runways in the Binghamton United States Engineer District, where Vinsol-resin cement was being used were inspected. It was reported that the chief reasons for adopting this cement were to overcome bleeding of the concrete, to provide more workable mixes, and to produce a more satisfactory surface. Observations of operations indicated that the use of treated cement practically eliminated water-gain and reduced segregation even when a high slump concrete was used. An examination of the surface of completed structures revealed no marked improvement, except that sand streaking was eliminated. It was reported that the addition of a small amount of Vinsol-resin resulted in a small reduction of compressive strength. The use of Vinsol-resin cement has caused no major change in the placing technique, except that finishing operations on the top of walls and slabs can take place almost immediately after the concrete is struck off. This cement tends to diminish or perhaps to obscure any undesirable effect that may result from overvibration.

c. Detailed reports on treated cement were obtained from Mr. M. A. Swayze, Director of Research, Lone Star Cement Corporation, Hudson, New York, and the Portland Cement Association, Chicago, Illinois. These reports concluded that addition of natural resins to cement produces concrete of greater durability, less permeability, improved workability, and reduced bleeding, but less strength, and that the optimum quantity to be added is from 0.02 to 0.03 per cent. Although some very favorable results have been obtained in laboratory tests and certain types of construction involving Vinsol-resin cement, it is believed that further investigation should be made before its use is specified for the locks and dams of the proposed project. One phase of such investigation should be a study of the relative durability of concrete in which treated and untreated cements are used. The study should include tests in a continuously saturated condition of freezing and thawing of lean mixtures of vibrated concrete, cured wet. This condition would simulate the exposure conditions of the concrete at the water line on lock and dam structures. As a result of the foregoing studies, it is recommended that the standard Moderate-Heat-of-Hardening Cement, Federal Specifications SS-C-206a, be used in the initial stage of construction, unless it is definitely established that treated cement is satisfactory in all respects.

18. ABSORPTIVE FORM LINING.- a. The fact that the concrete in the structures of the proposed St. Lawrence River project should be especially resistant to weathering and erosion led to consideration of the use of absorptive form lining for producing more durable surfaces. The appearance of the concrete as a result of the use of absorptive form lining was not a consideration in determining its use. Reports of investigations of absorptive form linings were obtained from the Bureau of Reclamation, the Tennessee Valley Authority, and the Binghamton Engineer

District. All the reports recommended absorptive form linings and gave evidence of increased durability, higher strength, greater resistance to abrasion and improved surface texture from its use.

b. During the tests of concrete made with various aggregates from this region, a limited number of concrete specimens were prepared using absorptive form lining. The results are shown under "Concrete Aggregate Investigation" in Appendix C. In accordance with the results of these tests and favorable reports from other investigations, absorptive form lining has been specified for use on forms for all surfaces of concrete in structures of the proposed St. Lawrence River project which will be exposed after the work is completed. Details regarding the use of absorptive form lining are given in the specifications for Long Sault Dam in Appendix III-22(2).

19. TEMPERATURE AND VOLUME CHANGE STUDIES IN MASS CONCRETE.- A limited study was made of problems pertaining to temperature control and surface cracking in mass concrete structures. Detailed requirements for reduction of cracking of the concrete are contained in paragraphs 5-08(d), 5-09(d), 5-09(f), 5-09(h), 5-09(i), and 5-11 of the specifications for Long Sault Dam, Appendix III-22(2).

20. STUDY OF PROTECTIVE COATINGS FOR FERROUS METAL.- a. A preliminary study of paint problems involved in the protection of ferrous metals was made, and consideration was given to the availability of paint materials which would best meet the existing conditions. The major requisite of the protective coating was considered to be ability to resist extreme ranges in temperature, strong sunlight, floating ice and debris, continuous and occasional submergence, and wave action. Recommendations were solicited from various governmental and industrial agencies in order to benefit from their experience with coatings under similar conditions. Information was obtained from the Tennessee Valley Authority; the Pittsburgh Engineer District; the Upper Mississippi Valley Engineer Division; the Rock Island Engineer District; Mr. A. K. Light, Chief Paint Chemist, Bureau of Public Works, Ottawa, Canada; and Dr. Frank N. Speller, Metallurgical Consultant for the third set of locks at Panama. The data from these sources indicated that the most satisfactory vehicle for the proposed project would be a varnish prepared from chinawood oil and pheno-formaldehyde resin. The pigments recommended for use with this vehicle were generally either aluminum or zinc dust with small amounts of various other pigments. Bitumastic coatings received both favorable and unfavorable comment from many sources.

b. In order to obtain further data pertaining to the experience of hydroelectric plants located in northern climates, inspections were made of the plants of the Beauharnois Heat, Light and Power Company, Beauharnois, Quebec; the Gatineau Heat, Light and Power Company, Ottawa, Ontario; and the Alcoa Plant, Massena, New York. Representatives of these companies were, generally, in favor of three coats of red-lead-linseed oil paint for the protection of ferrous metal surfaces. However, an inspection of several structures painted with the red lead oil system did not provide evidence of satisfactory protection. In view of these facts and in consideration of the probability that many materials used

in paint such as tung-oil, aluminum, and zinc could not be obtained because of defense priority, the specifications were prepared on the basis of thorough cleaning of the metal, phosphoric acid inhibition, and application of four coats of sand-reinforced enamel. The detailed requirements of the specifications are contained in Section X, Paints and Painting, of the specifications for Long Sault Dam, Appendix III-22(2).

c. The paint formulae used in the specifications are similar to those recommended by the Pittsburgh and Rock Island United States Engineer Districts. Substitution of certain oils and pigments was made since many standard materials were not available because of defense priority. It is recommended that availability of paint materials be ascertained immediately before their use is required. Test results on the metal primer paint (synthetic Red Lead Primer) including recommended adjustment of the formulae are in District File SCM-G-3/6. Aluminum pigment mixed in a 100% china-wood oil-phenolic resin varnish is considered most desirable for use as primer and finish coat, but this paint is not available at this time. Tests are now being made on Locks and Dams in the Upper Mississippi Valley which will provide information concerning the durability of paints made with substitute materials.

21. MATERIALS TESTING LABORATORY.- In view of the magnitude of the project, a materials testing laboratory at the site will be necessary. Work will include the design and control of concrete mixtures; control and acceptance of concrete aggregates; and testing of all other materials of construction. A compilation of the specifications and tentative requisitions of the apparatus and equipment are in District File SCM-V-3/0.

22. CRITERIA.- General criteria for guidance in developing the general plans and in carrying out the detailed designs were established initially and were modified as additional information was obtained. A general discussion of the principal criteria follows:

a. Excavation and Embankment.-

(1) Excavation Slopes.- The design and analysis of slopes varied considerably according to the problem involved and experience with similar materials. Stability of the slopes of canals and cuts in firm materials present no major problems. Ground water seepage may cause some difficulty at a few locations, however, such difficulty could be easily and quickly corrected during construction. A maximum slope of one on two was established for all proposed hydraulic and navigation cuts in firm material. This slope will reduce bank and channel maintenance to a minimum. Design values for excavation slopes in soft material required special study. Mathematical analyses were made for all slopes in clay using the shearing strengths obtained from the laboratory tests. Slopes were analyzed by several different methods in order to compare results. However, it was concluded that the "Circular Arc Method" of analysis was the most applicable, and all designs were based on results from this method. A maximum slope of one on two was established for permanent excavation in clay to reduce the maintenance resulting from minor failures or sloughing. All permanent slopes were designed with a factor of safety of at least 1.5, a value sufficiently conservative to eliminate

any possibility of a major slide. The various methods of analysis and the resulting slopes are described in the analyses of design for the specific structures.

(2) Earth Embankments.- The design criteria and analyses of earth embankments varied considerably, depending on the problems involved and the experience with similar materials. Generally, the top widths of the dikes and wing dams were dependent on the use of the embankments for highways and railroads, or otherwise. As the established crest elevations provided sufficient freeboard, settlement of the dikes was not a major problem and it was considered that all settlement would be corrected by subsequent maintenance. The primary design requirements for all earth embankments were, economy of construction, control of seepage, and the static stability of the structures. Dikes and wing dams which were located on firm foundations, where shear failure was not a critical factor, were designed primarily to reduce and control seepage and to eliminate excessive settlement of the structure. Provisions were made to compact the sections and to prevent or to control seepage through either the embankment or its foundation. In some instances where it was impractical to attempt prevention of seepage and even where seepage was believed to be negligible, sufficient drainage control features were incorporated in the design to provide adequately for any quantity of seepage that might develop. The design of earth embankments over the deep deposits of marine clay necessitated detailed studies of the extent and characteristics of the foundation material and extensive mathematical analysis of the sections. The main problem involved in the designs was the stability of the foundations. Because of the low shearing strength of the clays, very flat slopes were used. Usually the embankment consisted of a central section of compacted material flanked by uncompacted material. The central section was compacted in an effort to reduce the settlement within the embankment. The compaction was considered beneficial in all instances, especially so if either a highway or railroad was to be located on the structure. Because of the wide sections and impervious foundations, seepage was not a primary problem, however, all necessary precautions were taken. All sections were designed for a factor of safety of at least 1.5 against shear failure. Dike sections and analyses are described and discussed in detail in the design analyses for the various features.

b. Structures.- The structural design and criteria are discussed in the analyses of design for the principal features, such as the Long Sault and Iroquois Dams, the Massena Canal Intake Works, and the various locks, and are included in the appendices. Unit stresses for concrete were based on recommendations in the United States Bureau of Yards and Docks Bulletin No. 3Yb entitled "Standards of Design for Concrete." Unit stresses for steel and other metals were based on recommendations of the American Institute of Steel Construction. These recommendations are believed to reflect best current practice for the design and use of the respective materials. The criteria for water levels, ice pressure, and uplift were based on information furnished by the Canadian Department of Transport, as given in detail in Section II of the analysis of design for the Long Sault Dam (Appendix III-22(3)). Permissible unit loads for foundations were based on explorations and

analyses of the various materials at the respective sites. Practically all concrete structures will be founded on rock having an indicated bearing value far in excess of that required for any structure. Therefore, allowable unit bearing values are not a major consideration in the designs. The standard H-20 loading of the American Association of State Highway Officials was adopted in the case of highway loads, because of the probability for increase of highway loadings during the long life of the structures. For similar reasons, Cooper's E-70 railroad loadings with reduced impact allowances were used for permanent structures carrying railroad loads.

c. Navigation Channels.- (1) The following criteria are recommended for the design of navigation channels in Appendix C, paragraph 13, of the report of the Joint Board of Engineers, dated November 16, 1926;

> "In general, navigation channels are not less than 200 feet bottom width when flanked by two embankments, not less than 300 feet when flanked by one embankment, and not less than 450 feet when both sides of the channel are submerged.
>
> "In cases where navigation is carried through restricted stretches of river, a sectional area of 65,000 square feet is provided at mean stage. This is equivalent to a sectional area of about 70,000 square feet at high stages, and a maximum velocity somewhat less than 5 feet per second in such channels. In general, maximum velocities and channels 450 feet wide are used only in short stretches of river where the view is unobstructed and where cross-currents are not encountered. The minimum radius of curvature adopted is 5,000 feet with at least one-quarter mile of tangent between reversals. The alignment is drawn so as to eliminate cross-currents wherever possible."

The foregoing dimensions were intended for channels 25 feet in depth. These criteria were retained by the Engineers of the Department of Transport of Canada for the channels 27 feet in depth in the Original 238-242 Plan. The increase in depth of 2 feet with the retention of the same waterline width and side slopes resulted in bottom widths 8 feet less than those originally recommended. The adopted bottom widths at 27-foot depth are 192 feet, instead of 200 feet, for channels flanked by two embankments; 292 feet, instead of 300 feet, for channels flanked by one embankment; and 442 feet, instead of 450 feet, for channels in which both sides are submerged.

(2) With the exception of the depth, these criteria were substantially the ordinary standards used during the first two decades of the 20th century for the 20-foot depth improvement of the connecting channels between the Great Lakes. Because of increased commerce and the continued increase in the size of vessels navigating the Great Lakes, these connecting channels have been generally enlarged. During the past two decades, new criteria for the design of these connecting channels were gradually established. The new criteria provided for

greater width, better alignment, and elimination, insofar as possible, of curves through constricted channels. Straight courses are provided which can be marked by range lights. At bends, the channel is widened to permit ships to turn and pass with less danger of collision or stranding. These improvements have encouraged the development and use of still larger vessels on the Great Lakes. In view of the size of vessels which would use deep water channels through the International Rapids Section of the St. Lawrence River, the foregoing criteria for depth, width, and alignment of channels were retained, but the more modern practices outlined above have been followed in the details of channel design. A bottom width of 442 feet was used for practically all channels since both sides of most of them will be submerged, except for short intervals.

(3) Up-bound vessels on the Great Lakes - St. Lawrence River System sometimes navigate successfully against currents as great as 7 feet per second. However, such velocities are excessive and generally unsatisfactory for up-bound as well as down-bound vessels. It will be noted in the quotation in paragraph (1) above that the Original 238-242 Plan was designed for "a maximum velocity somewhat less than 5 feet per second." Later, in the Annex of the Joint Committee Report of 1941, the allowable velocity was lowered to 4 feet per second. The following is quoted from this annex:

> "(5) Channel enlargement from the head of Galop Island and below Lotus Island designed to give a maximum velocity in the navigation channel south of Galop Island not exceeding four feet per second at any time."

This last criterion was incorporated in the Annex of the International Agreement of 1941, and has governed the design of navigation channels by this District. In applying this criterion, it was felt that undue expense should not be incurred to prevent this velocity from being exceeded by a small margin for a short time, in short reaches, at rare intervals. Accordingly, the channels as designed permit an increase of velocity to a little above 4 feet per second for 3 per cent of the navigation season, reaching an extreme maximum of about 4.5 feet per second. All reaches of the project satisfy this criterion, but in only 2 reaches was it the governing feature of design. These two reaches are from Chimney Point to below Lotus Island (Mile 67 to Mile 74)* and from the Lower Entrance of Grass River to Lake St. Francis (Miles 107.6 to Mile 114). The design of all other reaches was controlled by the criterion for ice conditions.

d. <u>All Year Operation of Power Plant.</u>- A major problem of the proposed St. Lawrence River project was provision for continuous winter operation of the power plant without undue interference from ice. The Joint Board of Engineers in Appendix E of its report dated November 16, 1926, presented a solution to this problem. This solution was adopted in the Joint Committee Report of January 3, 1941, and incorporated

*All mileages refer to distance from Tibbetts Point. See Plate M (bound herein).

in the Original 238-242 Plan. No further study of the ice problem was made by this district. The following facts with respect to ice formation were presented by the Joint Board: (1) Where swift currents in the river prevent the formation of a fixed ice sheet, fine ice crystals, known as "frazil ice", form, float downstream, and lodge in quieter water or attach themselves to fixed objects; (2) a continuous ice cover will form over the river only when the average velocity is less than $1\frac{1}{2}$ feet per second; and (3) floating ice and slush will pack against the upstream edge of a fixed ice cover and will extend it upstream against average velocities less than $2\frac{1}{2}$ feet per second. The solution of the problem as adopted in that report was (1) to provide mean velocities not exceeding $1\frac{1}{2}$ feet per second so that natural ice covers will form, (2) install artificial barriers against which the floating ice will pack to start the ice sheet, and (3) wherever reasonably possible provide mean river velocities upstream therefrom not exceeding $2\frac{1}{4}$ feet per second. Under the proposed project, it is believed that a fixed ice cover will form over the pool for some distance upstream from the powerhouse and the Long Sault Dam and that the proposed channel enlargements will provide average velocities not exceeding $2\frac{1}{4}$ feet per second as far as Mile 79, thereby permitting a continuous ice cover to form between the powerhouse and Mile 79. The crest gates of the Iroquois Dam (Mile 77.5) can be manipulated so as to form a barrier against which the ice pack will form and, with the proposed channel enlargements, will extend upstream to the vicinity of Lotus Island (Mile 74). Above Galop Island (Mile 70.7) the proposed ice cribs and booms will constitute a barrier which will permit formation of the initial ice pack and its extension upstream to the downstream end of the natural ice cover which forms in the Thousand Islands Section. In the Galop Rapids between Miles 70.4 and 74.0 and in the section between Iroquois Dam and Mile 79, the criterion of mean velocities not exceeding $2\frac{1}{4}$ feet per second cannot be met, except at excessive cost. The criterion for navigation channels (paragraph 22c) governs the design of channels in the Galop Rapids Section. No improvement is recommended in the reach between Iroquois Dam and Mile 79. It is expected that these reaches will remain open during the severest winters, but that the amount of frazil formed in them will not be sufficient to cause serious difficulty.

e. Lock Dimensions.- The following criteria for locks are recommended in Appendix C, paragraph 15, of the report of the Joint Board of Engineers, dated November 16, 1926:

> "As stated in paragraph 113 of the Main Report, the locks conform in dimensions with those of the new Welland Ship Canal, and have chambers 859 feet in length between inner quoinposts and 766 feet between breast wall and fender. Their clear width is 80 feet and the depth on the sills 30 feet. The general design of a typical lock is shown on Plate I, Appendix C."

The Canadian Department of Transport followed these criteria in the Original 238-242 Plan, and they were used in the present studies.

23. HOUSING AND RELATED PROBLEMS.- a. Existing housing facili-

ties for U. S. Government and contractors' employees within dependable commuting distance of the proposed project works will be entirely inadequate during the construction period. While no study was made regarding the housing facilities for the Canadian portion of the work, it is understood that a similar housing problem will arise on the Canadian side.

b. The major portion of the proposed project is located in the reach downstream from Morrisburg, Ontario, Mile 85 (approximately opposite Waddington, N. Y.) and a lesser amount in the reach upstream from Morrisburg. The former subdivision will be referred to hereafter as the downstream division and the latter as the upstream division. In the downstream division, it is estimated that initially there will be approximately 1,000 U. S. Government employees and that at the peak of construction, there may be a total of approximately 1,500 such employees for whom housing facilities will be required. It is also estimated that 60 per cent of these employees will be married, necessitating housing for 600 to 900 families. A further study of the proposed construction schedules (see paragraph 34) indicates that at the peak of activity, there may be a total of approximately 20,000 contractors' employees for whom housing will also be required. The contractors' employees may be divided into two groups: (1) those working on the U. S. Government contracts and (2) those working on Canadian Government contracts. No estimate of the division of employees can be made until the International Commission decides the proportion of work to be allocated to each Government. It is believed that provision should be made for a semi-permanent camp of sufficient capacity to house the anticipated number of U. S. Government employees and their families. The name proposed for the camp is Seaway, New York, and the location recommended is approximately three miles east of Massena, New York, on the north bank of the Grass River. This location will be within easy commuting distance of the places where about 80 to 90 per cent of the total number of Government employees will work, and will also be sufficiently removed from all the important project works so that the inhabitants will not be disturbed by the construction activities. It is suggested that the operation of the facilities of the proposed village, including a commissary, school, hospital, fire and police departments, and utilities, be taken over by a town management division, independent of the construction organization and to a great extent of the normal Administrative Division of the District Office. Details of the proposed organization are contained under "Organization for Town Management" in Appendix III-21(3). The foregoing is based on the premise that the work will be performed under contracts. Should it be decided to undertake a considerable part of the work by hired labor methods, additional facilities, consisting principally of dormitories and mess houses will be required. Provision has been made for these additions without disrupting the general plan. See Appendices III-21(1), (2) and (3) for plans, specifications, analyses of design and general information.

c. A large percentage of the work in the upstream division (above Morrisburg) will be a highly mechanized operation requiring a much smaller proportion of labor than the construction work below Morrisburg. Living quarters for the Government employees assigned to this work will

probably be available in Ogdensburg, New York, and adjoining villages, or in contractors' camps, constructed in that section. It will also be possible for some employees to commute from Seaway if they desire. Construotion of a camp similar to that proposed for Seaway to house Government employees connected with the construotion of Iroquois Dam and the other work in that vicinity was considered, but deemed unnecessary because of the comparatively small number of Government employees who will be employed on that work.

d. It is expected that Seaway, N. Y. will be used for housing employees of the Government, but not for contractors' employees. It is believed that the matter of housing and caring for the contractors' employees should be left to the contractors and that all such arrangements and facilities established by the contraotors should be approved by the contracting officer. It is anticipated that many of the oontractors' employees will reside in trailers, and it is believed that the contractors should be permitted to use Government land wherever available for camp sites. The plans and specifications for various construction contracts oontain provisions governing the location and operation of such camps.

24. RAILROADS AND HIGHWAYS.- a. Present Facilities, General.- The area adjacent to the International Rapids Section of the St. Lawrence River is fairly well provided with transportation facilities. It is served by one main transcontinental railroad (Canadian National Railway) and a number of secondary lines, together with a fair net-work of public highways. The river itself, supplemented by the system of marginal canals on the Canadian side, is a major artery of oommerce for serving the project area either from the ocean or from the Great Lakes. Vessels using this route are limited to a length of 252 feet, a beam of 42 feet, and a draft of about 14 feet. Bridges provide a minimum vertical clearance of 120 feet. A large number of ships now using this waterway are able to carry a deadweight tonnage of 2,000 to 2,200 tons under present conditions. Vessels approaching the Great Lakes from the south can enter Lake Ontario at Oswego by means of the New York State Barge Canal, or Lake Michigan at Chicago from the Mississippi River System. Limiting dimensions on the New York Barge Canal are about as follows: length, 300 feet; width, 44 feet; depth on lock sills, 12 feet. Fixed bridges limit the overhead clearance on this route to 15.5 feet at normal pool stage (improvements now under oonstruotion will increase this to 20 feet above maximum navigable stage). Vessels coming from the Mississippi are limited to a draft of about 9 feet, and overhead clearances of about 17.5 feet at normal stage. Controlling horizontal dimensions of looks are 600 feet in length and 80 feet in width. Wharfage facilities for vessels navigating the St. Lawrence River are available at Cornwall, Morrisburg, Iroquois, Cardinal, Prescott and Brockville on the Canadian side, and at Waddington, Ogdensburg, and Morristown on the New York side. These facilities are adequate for the existing traffio, but might require expansion if large quantities of material for the proposed St. Lawrence project were shipped by water.

b. Canadian National Railway.- The Canadian National Railway,

an important transcontinental line, parallels the St. Lawrence River on the north side throughout the International Rapids Section with stations and freight facilities at Cornwall, Morrisburg, Iroquois, Cardinal, Prescott, Brookville, and smaller villages. It provides connections with Montreal and North Atlantic ports in the east and with Toronto, Chicago, Milwaukee, and other points in the midwest, and connects with Winnipeg and the Pacific Northwest by means of a line north of the Great Lakes.

c. Canadian Pacific Railway.- The Canadian Pacific Railway is another transcontinental line which parallels this section of the St. Lawrence River a few miles north of the Canadian National Railway. It has spur lines to Prescott and Brockville and connects with the New York and Ottawa Branch of the New York Central Railroad at Finch, Ontario.

d. New York Central System.- The St. Lawrence Division of the New York Central System comes in from the south to a terminal in the southern part of Massena, about three miles from the St. Lawrence River. This line is connected by way of Watertown with the main line of the New York Central at Utica, Rome, and Syracuse. A branch line leaves the St. Lawrence Division at DeKalb Junction and reaches the St. Lawrence River at Ogdensburg, at which point a car ferry provides connection to the Canadian National and to a branch of the Canadian Pacific Railway. A second branch of this Division reaches the river at Morristown. The New York and Ottawa Railroad of the New York Central System runs south from Ottawa, Ontario, connects with the Canadian Pacific Railway at Finch, Ontario, and with the Canadian National Railway at the western edge of Cornwall, and crosses the St. Lawrence River to Rooseveltown, thence to Helena where it connects with a branch of the Grand Trunk Railway. This line formerly continued about ten miles further south to connect with the Rutland Railroad. The track has been removed from this portion of the line, but the right-of-way still exists and the track could be relaid if the movement of large quantities of material from this direction becomes necessary.

e. Rutland Railroad.- This railroad runs roughly parallel to the St. Lawrence River and a few miles to the south. It has its western terminus at Ogdensburg and connects with the Massena branch of the New York Central System at Norwood, approximately 13 miles south of Massena. It proceeds eastward and affords connection with New England points and indirectly with New York City.

f. Grand Trunk Railway System.- A branch of the Grand Trunk Railway System, the American subsidiary of the Canadian National Railway, parallels the St. Lawrence River on the south side from Massena to Montreal. It connects with the southern end of the New York and Ottawa Division of the New York Central System at Helena. The New York Central System, which has trackage rights over the portion of the Grand Trunk Railway between Massena and Helena, operates freight trains between Massena and Ottawa via the Grand Trunk Railway and the New York and Ottawa Railroad.

g. Norwood and St. Lawrence Railroad.- The Norwood and St.

Lawrence Railroad leaves the St. Lawrence River at Waddington and connects with the New York Central and Rutland Railroads at Norwood. Its total length is approximately 18 miles and its rolling stock is very limited.

h. The Massena Terminal Railroad.- This railroad, a subsidiary of the Aluminum Company of America, extends from the terminal yard of the New York Central System and Grand Trunk Railroad in the southern part of Massena, through the village, and across the Grass River and serves the plants of the Aluminum Company of America and the Defense Plant Corporation, located between the Grass and St. Lawrence Rivers. It also serves a few small mercantile and industrial installations in Massena. Due to its grades and alignment and the condition of its two bridges, its freight handling capacity is somewhat limited, but it is understood that the management contemplates substantial improvements at an early date.

i. Railroad Terminal Facilities.- The aforementioned railroads have sidings and freight handling facilities at the points named. In general, these facilities are adequate only to handle the existing traffic. In order to handle the large volume of steel, aggregate, cement and other materials which will be required for the construction of the proposed St. Lawrence project, substantial enlargement of these facilities will be necessary. The railroad interests indicated ability and willingness to make the necessary enlargements when required.

j. Kings Highway No. 2.- This highway is the principal one on the Canadian side of the St. Lawrence River and parallels it quite closely throughout the entire length of the International Rapids Section, passing through all the villages between Prescott and Cornwall. It connects on the east with Montreal and the principal points in Quebec and the Maritime Provinces, and on the west with Toronto, the Niagara Frontier, and the region north and east of Lake Huron. Branch Highways Nos. 31 and 16 run north to Ottawa from Morrisburg and Prescott, respectively.

k. Highways in New York State.- United States Highway No. 11 parallels the river on the United States side about 20 miles to the south, and affords connections with the main east and west routes through the Mohawk Valley, which have connections with New England and New York City to the south, and with Syracuse and Buffalo and other points to the west. Three important New York State highways supplement the transportation afforded by this U. S. route. Route No. 56 connects Massena with Highway No. 11 at Potsdam. Route No. 68 connects Ogdensburg with the same highway at Canton. Route No. 37 parallels the river from Ogdensburg through Massena and continues east to intersect Highway No. 11 at Malone, New York. Route No. 37 reaches the vicinity of the river in only a few points, but several second-class gravel or bituminous roads follow the river and connect with this route at various points.

25. AIR TRANSPORTATION.- The nearest airports at which commercial airline service is now available are Syracuse, New York, distant 170 miles from Massena; Ottawa, Ontario, distant 69 miles; and Montreal, Quebec, distant 86 miles. Syracuse is served by the American Airlines, with connections to New York City and Buffalo, Chicago, and other western points.

Ottawa is served by Trans-Canada Air Lines connecting with Montreal, Toronto, and practically all major Canadian cities. Montreal is served by Trans-Canada Air Lines, by Canadian Colonial Airways affording service to Burlington, Vermont; Albany, New York; and New York City; and by Northeast Airlines connecting with Boston and other New England points. Airports at Massena, Ogdensburg, and Malone afford landing for planes of medium size, but have no scheduled air service at the present time. The airport at Massena is now in course of enlargement to accommodate the largest commercial transport planes, and the application of Canadian Colonial Airways for authority to provide service which will connect this village with Albany, Burlington, Watertown, Syracuse, Binghamton, and New York City, is now pending before the Civil Aeronautics Authority. Most of the aforementioned transportation routes are shown on the locality map on Drawing MC-1-1/3 in the Plans for the Long Sault Canal, Appendix III-16(1).

26. ADDITIONAL TRANSPORTATION.- a. The construction of the proposed St. Lawrence River project requires certain changes in and additions to the existing railroad and highway nets in order to handle the additional traffic which will exist during the construction period. A considerable portion of this increased traffic involves transportation of materials, of which the estimated amount is given in the following table:

Division	Material - Tons	
	Maximum, Annual	Average Annual (4 yr. period)
Upstream Division (above Morrisburg)	(1) 90,000	(1) 70,000
	(2) 1,285,000	(2) 980,000
Downstream Division (below Morrisburg)	3,325,000	2,000,000

(1) Based on obtaining concrete aggregates from rock excavation from the canal.
(2) Based on obtaining concrete aggregates from outside areas.

b. The problems of additional transportation facilities to the upstream division can be satisfactorily solved during the preliminary stages of construction, and therefore no definite recommendations are offered at this time. This division contains the channel work between Chimney Point and Canada Island, and the construction work in the vicinity of Point Rockway. The former requires heavy equipment, but relatively little labor and materials; the latter, which includes the Iroquois Dam and Point Rockway Lock, requires more men and materials, especially if concrete aggregates are shipped in. Suitable routes leading to these work centers can be developed without excessive cost or loss of time by utilizing and improving the existing roads. If rail connection is desired at Point Rockway, a spur approximately 7 miles in length from Norwood and St. Lawrence Railroad at Waddington can be easily constructed.

c. The transportation problems in the downstream division,

which contains the most important features of the work, were studied in detail since the greater portion of men and materials required for the proposed project will utilize the routes in this area. The project works involved in the upper 11-mile reach of this division, between Morrisburg and Richards Point (Mile 86 to Mile 97), consist only of relocation of railroads and highways on both sides of the river and construction of a few minor dikes on the United States side. No serious transportation problems are involved in this area. The reach below Richards Point contains the principal project work centers, including Seaway Village, Long Sault Canal and Locks, Long Sault Dam, and the Barnhart Island Powerhouse. Some of the permanent transportation facilities which require relocation because of the creation of the pool, and others which will be provided for access to the structures in this reach, can be utilized during the construction period. A permanent highway is necessary from State Route No. 37 near Massena to Seaway Village, thence to the Long Sault Dam and the Robinson Bay Lock of the Long Sault Canal. This highway requires a bridge across the Grass River near Massena. Upon completion of the dam, the permanent highway will continue over the dam and thence across Barnhart Island to the United States end of the powerhouse. A highway connection to the Canadian end of the powerhouse is proposed from Kings Highway No. 2 near Lock 19 of the existing Cornwall Canal. This highway will cross the canal by means of a combined highway and railroad drawbridge across the present Lock 19. Rail connections to these centers will be provided by constructing a single track line from the proposed yards of the Massena Terminal Railroad (to be located north of the plant of the Aluminum Company of America) to the Robinson Bay Lock, thence to the Long Sault Dam. A spur leading from this line to Seaway Village will also be required. Upon completion of the dam, the permanent railroad will continue over the dam and thence along Barnhart Island to the United States end of the powerhouse. A rail connection to the Canadian end of the powerhouse is planned from both the Canadian National Railway and the Ottawa Branch of the New York Central Railroad near the junction point located immediately west of Cornwall, Ontario. This spur will also cross the existing Cornwall Canal by means of the proposed drawbridge over the present Lock 19. Permanent highway and railroad connection to the Grass River Lock of the proposed Long Sault Canal will be available after the Roosevelt Highway and the Ottawa Branch of the New York Central Railroad are relocated along a route from Rooseveltown to the the Grass River Lock, thence across Pollys Gut to the original lines on Cornwall Island (see paragraph 69).

d. In addition to the permanent facilities, to be provided during the early stage, temporary transportation facilities will be required during the construction period. (See Chapter III, Paragraph 34a.) A temporary rail connection to the site of the United States end of the Barnhart Island Powerhouse can be provided by extending the aforementioned proposed spur crossing the present Lock 19 along the top of Cofferdam B, which will have sufficient width to accommodate the railroad. Another possible method for obtaining a temporary rail connection to the site of the United States end of the Barnhart Island Powerhouse, would be to construct a track across Cofferdam C, located downstream from the powerhouse. During construction of Long Sault Dam, a standard gage track will be provided across the river at the dam site by utilizing the top of the downstream cofferdams. This track will be built during the second stage

of construction and can, if desired, be extended to the site of the powerhouse. A highway connection to the Grass River Lock can be secured at first by extending the present highway along the north side of Grass River from Massena Center to the lock site. The temporary and permanent transportation facilities from the Canadian mainland to Barnhart Island, including the island end of the Long Sault Dam, are discussed at greater length in Chapter III under Features Nos. 24 and 29.

e. The problem of providing more satisfactory access to Barnhart Island during the construction period was given considerable study. At present, Barnhart Island can be reached by boats and a light cableway having a maximum capacity of about 8 tons, which crosses the South Channel at Hawkins Point. Better transportation could be obtained by (1) temporary bridges across the south channel at various points between the Long Sault Dam site and the present cableway (see Drawing MBRR-R-90/1, Appendix A-1); (2) an aerial tramway plus ferry service for bulk materials; (3) a belt conveyor supported by a light suspension bridge supplemented by ferry service; and (4) a cableway together with ferry service. (See Drawing MBZ-1-2/1, Appendix A-1.) The time required for construction would be approximately the same for each, but the tramway-ferry method is considered most desirable, since the greater portion of materials required at the powerhouse site, before the rail connection across Long Sault Dam becomes available, consists of concrete aggregates and cement. The most satisfactory location is from Hawkins Point to a point opposite on Barnhart Island. As soon as the relocation of the Ottawa Branch of the New York Central Railroad is completed across Grass River Lock, a spur approximately 2 miles in length can be constructed to Hawkins Point, thereby providing for delivery of the concrete materials by rail at the mainland end of the tramway.

27. ELECTRIC POWER FOR CONSTRUCTION.- a. Present Supply and Estimated Needs.- During the construction of the proposed St. Lawrence River project a large amount of electric power will be required to operate the various electrically-driven equipment, such as pumps, concrete mixers, air compressors and hoists, as well as for general lighting purposes. Electric power will also be required to serve the numerous buildings occupied by Government personnel and by contractors' employees. The areas involved in the United States part of the proposed construction are served by the Niagara Hudson system through its subsidiary, the Central New York Power Corporation. This corporation operates hydroelectric generating stations having a combined generating capacity of approximately 244,000 kw and steam generating stations having a combined capacity of 190,000 kw or a grand total generating capacity of 434,000 kw. The transmission system serves the area by primary distribution lines at various voltages and capacities. Massena is at present supplied with 3-phase, 60-cycle current by a double circuit steel tower line with a terminal voltage of about 118 kv. A new line from Taylorville to Massena, insulated for 230 kv, is now under construction. The town of Ogdensburg is served by a double circuit 80 kv line. Another line connects Ogdensburg with a hydroelectric development a few miles to the south. The intervening territory between Massena and Ogdensburg is served by light capacity lines. There is at present no way in which a large amount of power such as will be required at Iroquois Dam can be delivered at the site, although

at the time discussions were held with the power company officials, there was sufficient power available to provide the full estimated amount required for construction. The locations of the various existing lines are indicated on Drawing No. ST-F-1/1, Appendix A-1, and further data are in the District files. Analysis of Design and detailed cost estimates are contained under "Power Distribution for Construction" in Appendix A-2. A study of the power demand for the several construction load centers indicates that the total peak demand will be approximately 30,000 kva. Of this amount, 25,000 kva will be required for the downstream division of the work, Miles 97 to 113+, and 5,000 kva for the upstream division which centers at Point Rockway. A tabulation of the estimated distribution follows:

Downstream Division.

Barnhart Island Powerhouses	7,500 kva	
Long Sault Dam	5,500 kva	
Robinson Bay Lock	3,000 kva	
Grass River Lock	3,000 kva	
Seaway Village	2,500 kva	
Massena Power Canal	2,000 kva	
Guard Gate	1,500 kva	
Sub Total		25,000 kva

Upstream Division.

Iroquois Dam	3,000 kva	
Point Rockway Canal and Lock	2,000 kva	
Sub Total		5,000 kva
TOTAL		30,000 kva

The total peak demand of 30,000 kva would occur only if all contractors on the proposed project should demand their maximum allotments simultaneously. This condition may never develop, but since the estimated demand can be provided, it is considered advisable to have the power available for each contractor at all times. It should be noted that the foregoing estimates do not include power for electric dredges, and must be substantially increased if plant of that character is to be used.

b. Proposed System and Service.- The Central New York Power Corporation will furnish all power for the various sites. Sufficient 60-cycle power at 110 kv nominal voltage to supply the downstream division is available at high tension side of the power company's sub-station located at Building No. 25A in the Aluminum Plant at Massena, New York. In order to furnish power to the several distribution points in the downstream division, it is planned to transmit the energy at 110 kv nominal voltage, to a Government-owned substation to be constructed at the approximate center of the electrical load in this division. At this substation, the voltage will be reduced to a primary distribution voltage of 6.6 kv and the power will be transmitted to each individual load center for the various contractors on the proposed project. The distribution voltage was fixed at 6.6 kv to utilize transformers and switches now available at Fort Peck, Montana. Should this equipment not be available when needed,

distribution at 13.2 kv would be preferable because of the loads and distances involved. It is also considered that each contractor should be required to install his own transformers for reduction of the voltage to that required by his equipment. A second source of power for the downstream division may become available upon completion of the new 230 kv transmission line from Taylorville to Massena, New York. This high tension line is being installed primarily for the purpose of supplying power to a new Government-owned aluminum plant in the vicinity of Massena, and there will be a 13.2 kv bus at the substation for supplying the new plant. Should there be surplus power available at this substation, for use in the construction of the proposed St. Lawrence River project, a loop system at 13.2 kv could be built to serve the various load centers. Contractors will be required to transform from this voltage to that required by their equipment. This source of power will eliminate the need for new 110 kv transformers. Should the construction of Seaway Village be started before the transmission lines are completed, there will be temporarily available a maximum of 2,500 kva, at 7.0 kv at a transformer owned by the St. Lawrence River Power Company located near Building No. 25 at the Aluminum Plant. It will be possible to erect a temporary line to supply this power to the contractors at Seaway Village.

c. Power for the construction work in the upstream division will be available from a high tension power line of the Central New York Power Corporation at Ogdensburg, New York. The specifications for work in this division provide that the contractors are to make all their own arrangements with the power company for their requirements.

d. Drawings relating to construction power are contained in Appendix A-1. Drawing MBT-1-155/1 is a general plan of power distribution showing both 110 kv and 6.6 kv lines, also 13.2 kv lines, if used. Drawing MBT-1-155/2 shows construction details of the 110 kv transmission line.

e. The estimated cost of installation of a power distribution system for the downstream division of the project is given below. This cost is included in Chapter III under Feature No. 21 (Seaway Village).

Transmission line, 110 kv, single circuit,		
H frame wood pole construction..............	$10,600	
Engineering and Contingencies (about 18%)...	2,000	
Total..		$12,600
6.6 kv Feeders..............................	$95,400	
Engineering and Contingencies (about 18%)...	17,000	
Total..		112,400
Substation, 25,000 kva capacity.............	$78,000	
Engineering and Contingencies (about 18%)...	14,000	
Total..		92,000
TOTAL FOR POWER DISTRIBUTION SYSTEM..............		$217,000

f. The foregoing discussion covers the supply of construction

power to all features of the proposed project lying in the United States, and also those features which lie on both sides of the international boundary. It is expected that some of these features will be allocated for construction by Canada, with a corresponding reduction in requirements for power from the United States. Power from Canadian sources will be used for that part of the proposed project which will be allocated for construction by the Canadian Government. Possible sources are: The Ontario Hydro Commission, which has power lines near the site of the works; the Beauharnois Power Development at Beauharnois, Quebec; the Shawinigan Power Development at Shawinigan Falls, Quebec; and the Cedar Rapids Development at Cedar Rapids, Quebec. A transmission line from the latter powerhouse now passes near the site of the proposed Canadian construction work in the downstream division.

28. PROCEDURE PRIOR TO INITIATION OF CONSTRUCTION.- a. Under the terms of the International Agreement of March 19, 1941, the following must be accomplished before construction operations may be commenced:

(1) Authorization of the project through approval by the Congress of the United States and the Parliament of Canada, of the Agreement dated March 19, 1941, between the Governments of the United States and Canada, as published in House Document No. 153, 77th Congress, 1st Session. Following such approval, the Agreement provides that it shall be proclaimed by the President of the United States and be ratified by the King of Great Britain, and that it shall enter into force on the day of the exchange of the instrument of ratification and a copy of the proclamation, which shall take place in Washington.

(2) Appropriation of necessary funds.

(3) Appointment by the President of the American members of the Great Lakes - St. Lawrence Basin Commission proposed by the Agreement and the confirmation of these appointments by the Senate; appointment of the Canadian members of the Commission by the proper Canadian Governmental authority; and organization of the Commission, including the establishment of an office and employment of an engineering and administrative staff.

(4) Establishment of rules and regulations for the conduct of the Commission by exchange of notes between the two Governments.

(5) Preparation by the Commission of plans and specifications for the construction of the project works and transmission of same to the Governments for their approval.

(6) Allocation by the Commission of the construction works between the two Governments as approved.

(7) Designation of the construction agency to build the portion of the project works in each country.

(8) Preparation of detailed working plans and specifications by the designated construction agencies and negotiation of the

construction contracts, with the approval of the Commission, for the various construction items.

b. The preliminary plans and specifications prepared by the District Engineer in connection with this survey will materially expedite the preparation of detailed plans and specifications and the award of construction contracts. The procedure outlined in the preceding paragraph indicates, however, that some months will probably ensue after authorization of the project and appropriation of necessary funds before construction contracts on essential features of the project can be awarded or negotiated and actual construction operations commenced, unless special speed-up measures are instituted.

c. The following preliminary work, most of which will not form part of the final project works, will be required before major construction can start.

(1) Construction of Seaway, New York, a village for Federal offices and employees engaged on the project; and connecting highways and railroads to Long Sault Dam area, all as described in Chapter III, Feature 21.

(2) Construction of a highway and railroad to the Canadian powerhouse, including a bridge over Cornwall Canal at Lock 19, as described in Chapter III, Feature 29.

(3) Construction of a high tension transmission line, substation, and distribution system for the supply of power to Seaway and to contractors, including the purchase of high tension transformers and electrical apparatus, all as described in paragraph 27b.

(4) The relocation of a portion of the New York Central Railroad (Ottawa Branch), and the Roosevelt Bridge highway between Rooseveltown and Grass River Lock, including a combined highway and railroad bridge over the Grass River near the lock site, as described in Chapter III, Feature 35.

(5) Improvement and extension of the North Grass River Road from Massena Center to the Grass River Lock site, presently included in the Grass River Lock contract.

(6) Raising the transmission lines of the St. Lawrence River Power Company at the site of the Robinson Bay Lock, as described in Chapter III, Feature 36. These lines must be raised ultimately to provide the clearance required for navigation and this should be done before construction of the lock is started.

(7) The acquisition of lands should be carried forward to the point where the United States will have right promptly to enter upon and take possession of areas for construction camps, connecting roads and railroads, project works having early construction priority, etc.

(8) Funds will also be needed to complete the detailed plans and specifications, perform model tests, and accomplish other engineering work which must precede the awarding of the construction contracts for those features of the project having the earliest priorities.

d. If rapid construction of this project is required, provision should be made for the construction agencies selected in each country to undertake the preliminary works, mentioned in paragraph c above, immediately ratification of the agreement seems assured without awaiting approval thereof by the Commission, and the necessary funds should be made available therefor. The estimated cost of such works on the United States side (except as noted) is as follows:

Seaway, New York	$5,650,000
Connecting Routes on United States side	392,000
Access to Canadian powerhouse (work located in Canada)	568,000
Power distribution to construction areas	217,000
Relocation of highway and railroad between Rooseveltown and Grass River Lock site:	
Roosevelt Bridge highway	89,500
New York Central Railroad	189,000
North Grass River Road improvement and extension	95,000
Raising St. Lawrence River Power Company transmission lines at Robinson Bay Lock site	38,500
Initial Land Acquisition	1,000,000
Deferred Engineering costs on features with P-1 priority	418,000
TOTAL COST	$8,657,000

29. FORM OF SPECIFICATIONS.- The mission of this District, as set forth in the authorizing directives, includes the "preparation of preliminary plans and specifications." Question arose as to the form in which specifications should be prepared. At the present time, it cannot be definitely determined which agency of the United States will be designated to negotiate and administer the contracts; what form of contract will be used; whether some of the work will be done with Government plant and hired labor; what regulations governing contracts will be issued by the Commission; and which works will be allocated to the United States and which to Canada. Furthermore, at the present time laws and regulations governing such matters are changing very rapidly. Ac-

cordingly, it was recognized that these questions could not now be settled and all specifications were drafted on the basis of award of contract immediately after public advertisement and competitive bidding under regulations of the Corps of Engineers as existing in the summer of 1941. Should conditions require, these specifications could readily be modified to meet changing regulations or to provide for cost-plus or other form of contract, or for construction by hired labor.

30. PERSONNEL.- a. A competent engineering staff was organized in the St. Lawrence River District for studies and investigation contained in this report. A number of consulting engineers were engaged. Valuable assistance was obtained from engineers of the Office of the Chief of Engineers, U. S. Army, and of the Department of Transport and other organizations of the Dominion of Canada, and from the staff of the Hydro-Electric Power Commission of Ontario. Other engineers also furnished information and advice. It is not the usual policy of the Engineer Department to publicize the names of persons assisting in its investigations. However, since construction of this project may be delayed for some years, it is believed that a record of the various technical men associated with the present investigations, will be of value. Therefore, a list of the principal technical personnel associated with the investigation is included in Appendix A-2.

b. Due to the increasing defense activities, it was anticipated early in 1941 that difficulty would be encountered in recruiting adequate and qualified personnel, in connection with construction of the proposed project, especially in the various engineering positions. Preliminary studies were made to ascertain the best methods of handling the recruiting problem in order to develop a system that would prevent bottle necks in the construction from lack of qualified personnel. These studies included conferences with the District Manager of the 2nd Civil Service District, the local New York State Employment Office and Officials from the State Headquarters. A preliminary schedule of personnel required for the first eighteen months of construction was prepared, based on annual expenditures of $35,000,000. The number of employees in each of the four services included in the Classification Act of 1923 was estimated on the assumption that the overhead or Government cost would be 10 per cent of the annual expenditure or $3,500,000. The following distribution of funds among the four services was then used in computing the number of employees for each Division:

Administrative Division..............	15%
Engineering Division..................	15%
Operations Division...................	68%
Land Acquisition Division............	2%

The total yearly expenditure on this basis was then divided by the average annual salaries for the various services, as shown by the Civil Service Commission Statistics, to determine the number of personnel required in each of the four services. The number of employees of each grade of the various services was then determined by a ratio based on past experience. A summary of the estimates of additional Government personnel required follows:

	M Day	1 Mo.	3 Mo.	9 Mo.	12 Mo.	18 Mo.	Total
Total - All CAF grades	69	40	82	67	67	40	365
Total - All P grades	46	52	96	100	67	24	385
Total - All SP grades	92	134	225	224	126	64	865
Total - All CU grades	22	20	41	78	45	18	224
TOTAL	229	246	444	469	305	146	1,839

In addition, two recruiting trips were made by a representative of the District office to establish relations with business and civic leaders, schools, and other organizations, to assist in securing tentative applications for the various positions. Applications that were received as the result of these investigations, were classified and tentative selections were made to fill the positions that will be available immediately after authorization of construction. A follow-up system was established to keep in touch with the applicants and personnel records were kept up to date as far as possible. However, in view of the increasing employment resulting from the war effort, it is doubtful whether the employees tentatively selected would be available for the St. Lawrence project if it were now authorized. While any method of estimating the number of personnel required for positions would be approximate, it is believed that the proposed organization schedule is sufficiently accurate for use in the initial recruiting. In view of the depletion of most Civil Service Commission registers, the procedure of employing professional and administration personnel in the Government service is changing so rapidly that the most desirable method for recruiting for the positions provided for on the proposed "M Day Charts" will be dependent upon the prevailing policies of the Civil Service Commission and the War Department at commencement of construction.

31. INTRODUCTION. - This Chapter is devoted to a detailed description of the proposed project for the improvement of the International Rapids Section of the St. Lawrence River for navigation and power development. The proposed work is described by Features as listed in the following paragraph. Under each feature is a description of its nature and purpose, the work performed during the course of this investigation, a statement of the present status of the design and, where applicable, a statement of the work remaining to be performed before contracts for the construction of the feature could be awarded. The description of each feature includes a brief estimate of cost. More complete cost estimates for the project as a whole are included in Chapter IV and in Appendix IV-C, and detailed cost estimates for a number of the features are included in the Appendices pertaining to the features. Appendices are also submitted containing the contract plans, specifications and analyses of design for those features, the design of which has been completed.

32. LIST OF FEATURES. - The proposed project, including the necessary accessory work, has been divided into 39 Features, each of which forms a more or less complete work item which will be considered as a unit and discussed in this report. The list of features, beginning at the upstream end of the project area, is as follows:

Feature No.	Description	Mile *	Remarks
1.	Channel Work, vicinity of Galop Island	67-74	Includes all work in vicinity of Galop Island.
2.	Galop Island Ice Cribs, Groups A, B, and C.	69-71	
3.	Channel Work. Sparrowhawk Point Cut. Toussaints Island Cut.	74-76.5	
4.	Iroquois Dam and Dikes.	77-78	
5.	Alteration of Lock 25 and Attached Dikes	77.5	
6.	Rehabilitation of Iroquois, Ontario.	±78	
7.	Point Rockway Canal and Approach Channels.	76.5-81	Includes all work in canal except lock and attached dikes

* Miles from Tibbetts Point, see plate M-III (bound herein).

Feature No.	Description	Mile	Remarks
8.	Point Rockway Lock and Attached Dikes.	79.7-80.3	
9.	River Work between Point Three Points and Canada Island.	79.5-85	
10.	Rehabilitation of Waddington, N. Y.	±83.5	
11.	Rehabilitation of Morrisburg, Ont.	84.6-86	
12.	Relocation of United States Highways between Waddington and Massena.	83.5-100	Including bridges.
13.	Relocation of Norwood and St. Lawrence Railroad.	84-85.5	Including bridges.
14.	Dikes on U. S. side between Waddington and Croil Island.	89-96	
15.	Massena Canal Intake.	96-99.5	Including Canal Dike and Richards Landing Dike.
16.	Long Sault Canal including Dikes Nos. 1, 3, 5 and 6, and downstream approach channel.	97.107.4	Includes all work in connection with the Long Sault Canal except the locks, guard gate and attached dikes.
17.	Long Sault Canal Guard Gate and Dike No. 2	±101.4	
18.	Robinson Bay Lock and Attached Dikes.	102.5-103.4	
19.	Robinson Creek Drainage Ditch.	103-103.2	Drainage ditch for area cut off by dikes.
20.	Grass River Lock and Attached Dikes.	106.1-107	

Feature No.	Description	Mile	Remarks
21.	Seaway Village and Access Routes on the United States side.	101-104	Construction camp for U. S. employees.
22.	Long Sault Dam and Attached Dikes.	100-103.6	Including changes in Lock 21 and all river diversion work across Long Sault Island required during construction.
23.	Barnhart Island South Forebay Dike.	104-105.8	Dike extending from U. S. Powerhouse to high land near center of Island.
24.	Barnhart Island Powerhouse.	105.5-106.5	Including generating equipment, step-up transformers and high tension leads, switch gear and switch yards. (Note that the transformers and high tension equipment listed do not form part of the "project" and are not included in the project estimates. They are to be provided by and at the expense of the operating agencies.)
25.	Minor Dikes, Canadian Side	101-104.5	Minor detached dikes north of Bergen Lake.
26.	New Cornwall Canal Dike and Drainage Ditch	104.5-106.5	
27.	Relocation of Cornwall Canal.	105.5-106.8	All work in connection with relocation of Cornwall Canal except lock and guard gate.
28.	New Cornwall Lock, Guard Gate, and Part of Attached Dikes.	106-106.5	
29.	Railway and Highway to Barnhart Island Powerhouse from Canadian Side.	106-108	Includes all work to construct permanent access railroad and highway to Canadian Powerhouse.

Feature No.	Description	Mile	Remarks
			(con'd) including bridge across Cornwall Canal.
30.	Relocation of Canadian National Railway.	76-106	Including bridges.
31.	Relocation of Kings Highway No. 2.	76-105	
32.	Channel improvements below Barnhart Island Powerhouse.	105.5-107	Includes channel work between downstream arm of powerhouse cofferdam and Pollys Gut.
33.	Improvement in South Channel below Mile 107.4.	107.4-114	Includes all channel improvement work in south channel exclusive of approach to Grass River Lock.
34.	Cornwall Channel Enlargement.	108-110	Includes all work in north channel downstream from Pollys Gut.
35.	Relocation of Ottawa Division of the New York Central Railroad and Roosevelt Highway.	106.2-108.7	All work in connection with relocation of New York Central Railroad including bridges. Includes all work in connection with relocation of toll road across south channel except bridges. Grass River and Pollys Gut Bridges will be combined railroad and highway structures.
36.	Relocation of Transmission Lines of St. Lawrence River Power Co.	100-106	
37.	Lands and Easements in the United States	67-114	Includes minor villages, etc.
38.	Lands and Easements in Canada.	67-114	Includes minor villages, etc., but excludes Iroquois and Morrisburg.
39.	Clearing of Flowage Areas.	67-106.5	

33. <u>SEQUENCE OF CONSTRUCTION</u>.- <u>a</u>. The individual features of work which comprise the proposed St. Lawrence River project are located at intervals along the entire length of the International Rapids Section. The river is at present developed for navigation over a channel affording a controlling depth of 14 feet, and for the supply of power and other purposes at several industrial developments within the area. It is essential that the more important of these facilities be maintained during the construction period. The magnitude of the proposed St. Lawrence River project, the number of interrelated work items, and the effect of the construction on the present facilities, make it imperative that a comprehensive schedule be developed and followed throughout the building period. By the proposed construction, the present river will be transformed into a pool which will extend throughout the major portion of the International Rapids Section and will affect the regime of the entire section. The pool will be raised in stages, each stage affecting one or more details. Some items require completion before the sites are submerged, some can be more readily accomplished in the dry or behind low cofferdams before the water is raised, a few require completion to assist in maintaining present facilities, temporarily or permanently, and others can be more readily performed after the pool has been raised sufficiently to permit more effective operation of floating plant. After completion of the project, the present navigation facilities will be replaced or otherwise provided for, and provision will have been made to restore or continue other facilities affected. In scheduling operations, the availability and distribution of construction equipment, particularly dredging plant, must also be considered.

<u>b</u>. Navigation now proceeds through the International Rapids Section (see paragraph 7a) by means of the following marginal canals which by-pass the rapids and reaches of swift water: The Galop Canal around the Galop Rapids and swift water downstream to the town of Iroquois; the Rapide Plat (Morrisburg) Canal around the Rapide Plat; the Farran's Point Canal around the swift water at the head of Croil Island; and the Cornwall Canal around the Long Sault Rapids and the swift water downstream to a point below Cornwall. Each of these canals will be affected during the construction period, particularly the Cornwall Canal, which extends past the sites of both the Long Sault Dam and the Barnhart Island Powerhouse. See Plate M-1.

<u>c</u>. The present Cornwall Canal will be altered for use during construction and after the project is in operation, by closing the canal in the vicinity of the Barnhart Island powerhouse left abutment and providing along the left bank a by-pass canal, including a new lock and dikes, extending from the powerhouse forebay downstream to a point in the old canal just upstream from Lock No. 19, a distance of about one mile. Creation of the upper pool prior to the completion of this new work would cause damage to the canal and locks downstream from the powerhouse by flooding, and would probably also result in flooding and extensive damage to the town of Cornwall. Flooding of the existing canal above the powerhouse, after the aforementioned new works are completed, but before navigation can be routed through the Barnhart Island North Channel in the St. Lawrence River proper, would create a serious hazard to, and probably interrupt, present navigation by submerging the existing

canal dikes and structures. The several stages of construction during which that portion of the Cornwall Canal above the powerhouse must be protected and the measures proposed to be taken are as follows:

(1) During the second stage of construction of the Long Sault Dam (see paragraph 33h(2)) the flow through the Long Sault Island diversion cut will raise the upper pool at Lock 21 at the head of the Cornwall Canal (about 5 miles above the powerhouse), to an elevation which will interfere with navigation by flooding the canal dikes and structures. Prior to that time, therefore, Lock 21 and the Cornwall Canal banks down to Sheek Island (about 4 miles above the powerhouse) must be raised to protect the part of the canal above the upstream Long Sault Dam cofferdam against flooding and to provide for the conditions explained below.

(2) During the early closure period of the Long Sault Dam (third stage of construction), the water surface at the dam will be raised by stages to elevation 209. The work previously performed in raising Lock 21 and the canal bank to Sheek Island will protect the canal above Sheek Island. The upper powerhouse cofferdam, located between Barnhart Island and Sheek Island, will be raised to elevation 213 to protect the canal below Sheek Island against flooding.

(3) During the later part of the closure period of the Long Sault Dam, the pool will first be raised to elevation 225, and then to elevation 235. Prior to creation of the pool at elevation 225, the new Cornwall Canal and Lock will be in operation and the present canal at the powerhouse left abutment will be closed. Upon creation of the pool at elevation 225 or higher, the 14-foot navigation can either be transferred to the New Long Sault Canal on the United States side, or can be resumed in the Canadian canal system, provided the split in the upper gate of the New Cornwall Canal Lock, described in paragraph 62c(1), is placed at elevation 211. By either method, interruption to navigation will not exceed one week or ten days.

d. The Farran's Point Canal will be flooded when the pool is raised to about elevation 207. However, no temporary construction measures will be required since the increased cross sectional area of channel from the higher stage and the decreased slope will lower the river velocities sufficiently to permit navigation through the open river channel at elevation 207 or higher.

e. Lock 23, the downstream entrance to the Rapide Plat (Morrisburg) Canal, will be flooded when the pool is raised to elevation 225. It will be necessary to complete the excavation of the Ogden Island west, middle and east cuts (Feature No. 9) prior to the creation of this pool in order to permit navigation to use the open river channel.

f. Lock 25, the lower entrance to the Galop Canal, will not be affected by the raising of the pool until the water is raised to operating level, elevation 238. However, the natural control caused by the constricted cross section at Point Three Points must be retained until the pool has been raised nearly to this level. Otherwise the flattened

slopes resulting from excavation in the Ogden Island section would reduce the depth on the lower sill at Lock 25 to a point where 14-foot navigation could not be maintained. The Galop Canal will not be affected by the raising of the pool. However, after the river is closed by the construction of the Iroquois Dam, down-bound navigation could not use the open river between Lock 28 and Iroquois, Ontario, as at present, but will be required to continue down the canal and re-enter the river at Lock 25. The excavation of the new cuts through Galop Island and the Galop Rapids will be planned so that no material enlargement of the hydraulic capacity of this section will occur until construction of Iroquois Dam is advanced to the point where it can control the flow of the river. Lowering of the water levels of Lake Ontario and the Thousand Islands Section will thus be prevented, and navigable levels in the Galop Canal above Lock 27 will be maintained until the Point Rockway Lock is completed.

g. The Massena Power Canal serves the Aluminum Company of America, the major power and industrial development along the river. The nation's need for aluminum makes it mandatory that the operation of this canal be maintained. Therefore, the construction of the new Massena Canal Intake Works must be so scheduled that operation of the canal will not be interrupted by changes in water levels. It will be necessary to abandon the Sheek Island Powerhouse at the beginning of construction. The other power and industrial facilities obtain water from the Cornwall Canal below Lock 20 and will not be affected provided the necessary water is passed through the Cornwall Canal System.

h. The construction of the Long Sault Dam has been scheduled for completion in about 4 years, in accordance with the progress proposed for the Barnhart Island Powerhouse. This schedule requires continuous construction, which is expected to be possible since there is no seasonal flood problem. However, ice conditions will preclude performing some of the work during the winter months. It will be necessary to place the cofferdams during the spring or fall periods, and it is advisable to make final closure during the ice free season. With the exception of these two items, the time required for each phase of the operations is roughly proportional to the volume of work involved. The following sequence of construction is proposed:

(1) First Stage.- The completion of the south section of the dam. Water levels in the river will not be disturbed except at points near the dam in the channel south of Long Sault Island. Time required is approximately 15 months.

(2) Second Stage.- The construction of the north section of the dam. The flow in the North Sault Channel will be diverted across Long Sault Island and the pool raised to elevation of about 206.5 at Lock 21. Time required is approximately two years.

(3) Third Stage.- The closure of the structure and progressive raising of the pool from elevation 206.5 to 238., completing the Long Sault Dam. Time required is approximately six months.

34. WORK SCHEDULE.- It is planned that the proposed project will be completed within the 4-year program to the extent of providing a 27-foot navigable channel, and installing 3 generating units of 55,000 KVA each, in each half of the powerhouse. Additional generating units in each half can thereafter be available for operation at intervals of 4 weeks. The work schedule for the individual features has been arranged to meet the requirements of the interrelation of the items, of the time for construction of each phase, and of the probable availability of equipment. The powerhouse, being the largest single item and requiring the longest construction period will govern the project schedule. Its progress will establish the time at which the pool can be raised by the closure of the Long Sault Dam. The progress on the Long Sault Dam, in turn, will govern the raising of the pool and thus control the construction of the numerous other features dependent on pool stages. A list of contracts for all items of the proposed St. Lawrence River project is included under "Contracts" in Appendix III-O(3). It is to be noted that the contract numbers do not agree with the feature numbers used throughout the rest of this report. However, they do correspond with the items of work as set up in the plans, specifications and design analyses. Appendix III-O(3) also includes under "Contracts" a construction program based on completion of the project, to the extent described above, in four years from the date of commencement of work, and on the assumption that work is started in the spring. If commenced at other seasons, some adjustment of the program will be required. The program is also based on accomplishing approximately 4,600,000 cubic yards of dredging in each of the four years. If sufficient equipment cannot be secured, adjustments in the dredging schedule will be needed. In such a case, some of the dredging, as the removal of Morrisburg Canal bank, etc., can be deferred. Concrete construction during the winter season is contemplated. This procedure may not be necessary in the case of certain structures, as for instance, Point Rockway Lock. The chart of the construction program does not include the time needed for procurement of materials and equipment. With regard to generating units, it is contemplated that the first three units will be ready in each powerhouse at the end of the fourth year, and thereafter one unit will be completed each month in the American powerhouse. Additional units in the Canadian powerhouse can be installed as required. In the development of the proposed project schedule, the foregoing conditions as affecting each phase were considered and each feature was assigned to one of four priority groups. The basis for the priority assignments is explained below.

a. Priority P-0.- Preliminary organization and construction, either temporary or permanent, which must be accomplished prior to or during the early stages of construction. This classification includes housing and office facilities, access roads, bridges, and other facilities necessary for the delivery of equipment and materials to the sites of the work. The following features are included:

(1) Seaway Village (Feature No. 21).
(2) Access highways and railroads included in the various structural contracts.
(3) Bridges for access routes.

(4) Access to the site of the Canadian Powerhouse (Feature No. 29).

(5) Relocation of portions of the New York Central Railroad, including construction of the Grass River Bridge, and relocation of part of the Roosevelt Highway (Feature No. 35).

Since the aforementioned items must be completed prior to the beginning of construction of the project proper in order to provide for the care of personnel and to permit transportation of equipment, materials, and employees to the work sites, they have been assigned priority over all others. The priority for Grass River Bridge is based on the premise that the construction of navigation facilities will be undertaken at the same time as the other features.

b. Priority P-1.- Permanent project works, the construction of which must be started immediately after authorization of the project. They consist of items which require early completion or which have long construction periods. The following are included.

(1) Channel Work, Chimney Point to Lalone Island (Feature No.1).- This involves considerable work in the present natural control which regulates the discharge from Lake Ontario, and it is highly important that the progress of the work be scheduled so that this natural control is not rendered ineffective until the Iroquois Dam is available for use as the control structure. The work on this feature is not otherwise appreciably affected by varying pool stages nor by any other work. The item is classed as first priority because of the large quantity of work involved and the length of time required for its completion.

(2) Sparrowhawk Point Cut (Feature No. 3).- This feature is affected by other work because a part of the dredging is proposed to be performed after the pool has been raised sufficiently to permit more effective maneuvering of the construction plant. A large part of the work can be accomplished during the early stages of the project. The completion of such work is desirable in order to release equipment for other work. Because of the large volume of excavation to be performed, this work should be expedited.

(3) Iroquois Dam and Dikes (Feature No. 4).- Operations on the Iroquois Dam and appurtenant dikes will not be directly affected by changes in pool levels resulting from the Long Sault Dam construction until the third stage is reached. However, early completion of the Iroquois Dam is desirable because the structure will provide the ultimate control of the discharge of Lake Ontario and therefore must be completed before the work upstream of the dam has reached the stage at which the existing natural control is no longer effective. Its early completion is also desirable in order to provide a measure of control over high river discharges during the closure of the Long Sault Dam, and thus reduce construction difficulties. The Iroquois Dam has been assigned first priority and scheduled for completion during the first $2\frac{1}{2}$ years of the construction period.

(4) Point Rockway Lock (Feature No. 8).- It is desired that this lock be available for use before operation of the Iroquois Dam is begun. Navigation could thus use the lock as soon as the pool is raised to elevation 225.

(5) Massena Canal Intake and Appurtenant Works (Feature No. 15).- The new intake structure must be completed during the first stage of construction of the Long Sault Dam and before the cofferdams for the second stage are completed, so that the discharge into the canal can be regulated when the pool is raised above the normal range.

(6) Long Sault Canal Excavation, Grass River Lock Excavation, Dikes Nos. 1, 3, 5 and 6 (Feature No. 16) and Drainage Ditches (Feature No. 19).- During the closure of the Long Sault Dam, navigation will be maintained in the present Cornwall Canal until the pool is raised above elevation 209. The Cornwall Canal will then be closed, the pool raised rapidly to elevation 225, and 14-foot navigation on the Canadian Canal system will be routed through the new Long Sault Canal and Locks. Considerable quantity of work is involved in the canal and lock excavation. This work must be commenced at an early date in order to complete the canal and lock construction by the desired time, and to enable excavation of certain portions in the dry. The contract will include the drainage ditch south of Long Sault Guard Gate and other drainage in connection with the construction of the canal.

(7) Robinson Bay Lock, Dike No. 4 and Adjacent Portion of Dike No. 3 (Feature No. 18).- As stated in (6) above, it is necessary for the Long Sault Canal to be in operation prior to creation of the pool above elevation 209. In order that this may be accomplished, the construction of Robinson Bay Lock must be expedited. As suitable material from the lock excavation will be used in the dikes, construction of the latter will progress with the lock and must be completed, before creation of the pool.

(8) Grass River Lock and Dikes 7 and 8 (Feature No.20).- This item is a part of the Long Sault Canal system and early completion is necessary in order that the canal can be in operation when the pool is raised.

(9) Long Sault Dam, Dikes, and Channels (Feature No. 22).- The Long Sault Dam is one of the major structures, second in size and importance only to the powerhouse. Therefore, this item is a first priority structure, scheduled for completion at the earliest date compatible with the progress of the powerhouse. The construction schedule of the Long Sault Dam is described in paragraph 33c.

(10) Barnhart Island South Forebay Dike (Feature No.23).- This work is a part of the powerhouse and should be completed before the pool is raised above elevation 210, since the upstream cofferdams protect the powerhouse area only up to this pool elevation. The fill can be obtained from material excavated from the powerhouse site and the construction conforms to that of the powerhouse.

(11) Barnhart Island Powerhouse (Feature No. 24).-

This is the largest single item of the project and requires the longest time for construction. In considering the stage of completion necessary for the powerhouse before creation of the pool, several important factors must be considered. Among these factors is the provision of the International Agreement that all structures will be designed for a maximum water surface elevation of 249. An understanding should be reached that during stages of construction, and for sometime thereafter, the powerhouse will not be subjected to pressures from water surfaces greater than that of the initial pool permitted by the Agreement; namely, elevation 238. This head should then be used in computing the stability of the partially completed structure. To advance the date of raising the pool, consideration should be given to omitting the speed rings and the concrete scroll cases of all the later units from the first construction. Then with head gates or stop logs placed in the head gate slots, the stability of the structure will be ample under the head of the reduced pool. Raising of the pool could be started upon completion of the powerhouse by the method and with the exception as noted herein.

(12) Powerhouse Mechanical and Electrical Equipment (Feature No. 24).- This includes turbines, governors, generators, etc., items which are not required until the powerhouse is partially completed. However, because of the long time required for their manufacture, the contract for their construction must be awarded promptly.

(13) New Cornwall Canal (Feature No. 27) and New Cornwall Lock and Guard Gates (Feature No. 28).- The ultimate function of these items is to provide a link between the Cornwall Canal below the powerhouse, and the pool above the powerhouse. This item must be completed at an early date for use of navigation at the present canal level, and work on the powerhouse dike across the present canal must be completed prior to creation of the pool. In order that the powerhouse dike across the present canal may be completed without hindrance to navigation before the pool is raised sufficiently to endanger the canal below the powerhouse, the new canal will be provided with an entrance into the present canal above the powerhouse, and the upper sill of the new lock will be placed low enough to permit the use of the new lock at present canal levels. The upper gate will be a split gate so that after the pool is raised the lower sections will be left in a closed position. During the first winter season thereafter, they will be removed and the sill raised.

c. Priority P-2.- Permanent works, the construction of which may be deferred until the P-1 project works are in progress, but which must be completed before the pool is raised to operating level. This includes the following features:

(1) Toussaints Island Cut (Feature No. 3). - This work is independent of other construction. However, it is more economical to perform the excavation in the dry prior to the raising of the pool, and the dredging after partial raising of the pool. The excavation will be of long duration because of the large quantity of material involved.

(2) Alteration of Lock 25 and Attached Dikes (Feature No.5).-

Although scheduled for the early stages of project construction, the work involved in raising lock 25 is of short duration and could be delayed until the winter season just prior to completion of the Iroquois Dam. The work on the locks should be performed during the winter season so that navigation will not be interrupted. The earth fill on the adjacent canal banks may be made during the summer months.

(3) Rehabilitation (Features Nos. 6, 10, and 11).- This work which comprises rehabilitation of Iroquois and Morrisburg, Ontario, and Waddington, New York, can be accomplished during the intermediate stages of the project.

(4) Leishmans Point and Ogden Island Cuts (Feature No.9).- Completion of a portion of the Ogden Island cuts is required prior to the closure of the Long Sault Dam to permit navigation through the river channel when the Morrisburg Canal is flooded. With this exception, the work need not be completed prior to the final raising of the pool. The schedule of the work is governed to some extent by the economic advantages of performing certain excavations in the dry, behind low cofferdams, before the pool is raised, and of performing dredging work after the pool has been raised sufficiently to permit better maneuvering of plant.

(5) Canada Island Cut and Removal of Morrisburg Canal Dike (Feature No. 9).- This work can be deferred until the pool is raised sufficiently to permit up-bound 14-foot navigation to use the open river. However, because of the volume of work involved, initiation of construction should not be unduly delayed.

(6) Point Three Points Cuts (Feature No. 9).- The Point Three Points reach forms a natural river control which partially governs the water surface at the foot of Lock 25. The natural control must be maintained so as to provide navigable depths at Lock 25 until either the pool has been raised or alternate structures built. It is also important that the cut be completed prior to the first ice season after the final raising of the pool. Since the depth above the lower sill of Lock 25 is more than two feet greater than that of all the other locks, a considerable amount of dredging could be performed at Point Three Points before navigation will be hindered. This work need not be initiated until after the first stages of construction have been started. Because a large part of this excavation can be done in the dry, it will be partially completed during the first stage.

(7) Railroad and Highway Relocations (Features Nos. 12, 13, 30, 31 and 35).- These features must be completed before the pool is raised by the closure of the Long Sault Dam. The period of construction, however, is such that they have been assigned second priority, except for portions of Feature No. 35 which will be used as access roads and bridges, and which have been included in the preliminary work.

(8) Coles Creek Dike, Bradford Point Dike, and Louisville Landing Dikes (Feature No. 14).- These items must be completed prior to, or immediately after, the beginning of closure of Long Sault Dam to

insure against flooding of adjacent areas by the rising pool.

(9) Long Sault Guard Gate, and Dike No. 2 (Feature No. 17).- Completion of work prior to closure of the Long Sault Dam is required to prevent flooding of the Long Sault Canal by the rising pool, and to route navigation through the canal at that time.

(10) Raising Lock 21 (Feature No. 22).- Although Lock 21 and the upper Cornwall Canal will ultimately be replaced by the new Cornwall Canal and Lock at the powerhouse, it is necessary that the present canal be maintained for navigation until the new Long Sault Canal can be used. (See par. 56d.) This lock would be endangered by the higher river stages which will exist at that point during the second stage of construction of the Long Sault Dam, and would be submerged during the third stage. For this reason, Lock 21 and the river dike of Cornwall Canal between Lock 21 and the cofferdam extending from the Canadian shore to Long Sault Island must be raised prior to the initiation of the second stage of the Long Sault Dam Construction; and the entire canal dike on the river side from Lock 21 to Sheek Island must be raised prior to closure of Long Sault Dam. In order that navigation will not be hindered, the work of raising the lock must be done during the first winter, and the dike raised before the following fall.

(11) Bergen Lake Dike No. 1, Moulinette Dikes 1 and 2, Mille Roches Dike 1, New Cornwall Canal Dike and New Cornwall Canal Drainage Ditch (Features Nos. 25 and 26).- The work must be completed before the pool is raised above elevation 210 during the closure of the Long Sault Dam.

(12) Dredging at Mouth of Grass River and in South Cornwall Island Channel (Feature No. 33).- Work must be completed before navigation is routed through the Long Sault Canal during the closure of Long Sault Dam.

(13) North Cornwall Island Cut (Feature No. 34).- The purpose of the cut is to aid in reducing velocities in the Cornwall Island South Channel. The work must be completed before navigation is routed through the new Long Sault Canal.

(14) Transmission Line Relocation (Feature No. 36).- The removal of the substation located on the canal bank, and the relocation of the Hydro-Electric Power Commission Transmission Line must be accomplished before the New Cornwall Canal is completed. However, completion of the canal is governed by the construction of the New Cornwall Lock, which will require a much longer period than the canal excavation. Therefore, the transmission line relocation will not be required until first priority items are in progress.

(15) Clearing Flowage Areas (Feature No. 39).- While the work of clearing must of necessity be completed ahead of the rising pool, it need not be initiated during the earliest stages of the project except in the immediate vicinity of early priority structures, which work is included therein.

d. Priority D.- Deferred items or project works which may be accomplished after the pool is raised to operating level. The following features are included:

(1) Galop Island Ice Cribs and Booms (Feature No.2).- The function of these cribs is to aid in forming and holding an ice cover during the winter months after the project is in operation. The work can be deferred without adversely affecting the project until items of higher priority are completed.

(2) Crab Island Cut and Tailrace Cut Outside Cofferdams (Feature No. 32).- The primary purpose of this work is to lower the tailwater and thus provide additional head for power. Since the full generator capacity of the plant will not be installed until sometime after the final pool raising, the extra head will not be required and the work may be deferred until other more urgent items have been completed.

DETAILED DESCRIPTION OF FEATURES

35. FEATURE NO. 1 - CHANNEL WORK, VICINITY OF GALOP ISLAND.-

a. Description and Purposes.- Work includes excavation of a system of channels through the Galop Island Section of the river, Miles 67 to 74. Channel improvement is necessary to provide for suitable deep draft navigation through the reach, as well as for hydraulic purposes, to create conditions which favor the economical development of power at the Barnhart Island powerhouse, and also to prevent a rise in the water levels in Lake Ontario from backwater of the pool. In order to provide the desired navigation facilities, the following requirements must be met:

(1) Channels of sufficient width and depth should be provided.
(2) Mean velocities should not exceed 4 feet per second under ordinary river conditions.
(3) Channels should have reasonably straight alignment.
(4) Entrance at each end of navigation channel should be easy.
(5) Troublesome cross currents should be avoided.
(6) The existing 14-foot navigation should be maintained during the construction period.

The following are governing considerations in connection with production of power:

(1) The channels should be designed to provide the greatest available head at the powerhouse.
(2) Channels should be enlarged sufficiently to prevent a rise in the levels of Lake Ontario from backwater of the powerhouse pool, and to permit the maximum discharge required under

Regulation Plan No. 5. (See paragraph 11e (2).)

The foregoing requirements must be carried out in such a manner that no change in the existing maximum and minimum levels of Lake Ontario is caused during construction or after the proposed project is in operation. Extensive changes in the existing channels are necessary to meet these requirements but as stated in paragraph 22d, it is not reasonably possible to provide mean velocities in this reach which will permit the formation of a winter ice cover. The outlines of the proposed channels are shown on Drawing GC-R-1/1, Appendix III-O(1). Memoranda on studies of the hydraulic problems are contained in Appendix A-2. For reasons given in paragraph 34b(1), P-1 priority has been assigned.

b. Treatment Under the Original 238-242 Plan.- The Original 238-242 Plan included provision of a channel 500 feet wide through Galop Island and the north end of Dixon Island, for hydraulic purposes, and a navigation channel varying in width from 1,000 feet to 600 feet passing south of Chimney, Butternut and Galop Islands, and cutting away the north sides of Lalone and Lotus Islands. Subsidiary features of this plan are: the removal of Spencer Island Pier, the Gut Dam, the bank of the Galop Canal, and portions of Locks Nos. 27 and 28; the construction of an additional channel for hydraulic purposes south of Lalone Island; construction of a guide pier located on the north side of the navigation channel at the southeasterly corner of Galop Island and ice cribs located across all channels to encourage the formation of an ice cover on the river above Galop Island. (See Plate M-II).

c. Additional Data Secured.- Recent and more comprehensive soundings throughout this reach of the river were taken by the United States Lake Survey. In addition, surveys, borings, and probings were taken by this office to determine more fully the character of the overburden, the river bed, and the underlying formations. Consideration of the more complete data now available has led to various modifications in the design of these channels. A detailed description of the methods and results of the subsurface explorations conducted in 1940 and 1941 is contained under "Subsurface Investigations for Navigation Channels and Hydraulic Cuts" in Appendix III-O(3) and accompanies Drawings GC-A-2/1-10 and GQC-A-2/1.

d. Recommended Plan. (Modification of the Original 238-242 Plan.) Computations by the District Office indicated that the maximum velocity in the Original 238-242 Plan was slightly greater than the 5 feet per second specified in the Joint Board Report of 1926. A maximum velocity of 5.4 feet per second was found in a constricted section in the navigation channel south of Galop Island. Using either, however, 5.0 or 5.4 feet per second, it is obvious that this plan does not satisfy the new criterion set up in the Annex of the International Agreement of 1941, that the maximum velocity in the navigation channel south of Galop Island be not more than 4.0 feet per second. Accordingly, studies were made to determine what changes should be made in this plan to reduce the velocity to the specified limit. These computations indicated that by widening the cut through Galop Island from 500 to 850 feet, the maximum velocity in the south Galop channel could be reduced to 4.6 feet per second. This maximum

velocity would obtain at a discharge of 310,000 c.f.s. with lake level at elevation 246.5 and occur about one month in 80 years. A velocity of 4 feet per second would be exceeded only about 3% of the navigation season, which may be considered as satisfying the requirements in the Agreement. The hydraulic computations are discussed in detail in Appendix A-2.

As a result of these studies, the Original 238-242 Plan in Feature No. 1 has been modified by increasing the width of the cut through Galop Island from 500 to 850 feet. The width of cut through Lalone and Lotus Islands was also increased slightly to reduce velocities and make the bend in the navigation channel easier at this point. Minor changes in the original channel alignment have also been made at other localities as described under Features 3 and 9.

The above described modification of the Original 238-242 Plan is hereafter designated as the "Recommended Plan." The outline of this is shown on Plate M-1. Details of Feature No. 1 are shown on Drawing GC-R-1/1 in folio entitled "Miscellaneous Features Plans."

e. Alternate Plan for Navigation Channel through Galop Cut. In connection with the studies for channel improvement at Galop Island to meet the limiting requirement of 4 feet per second velocity in the navigation channel, various plans were studied in addition to the previously described Recommended Plan. These studies included a straight navigation channel through Galop Island without enlargement of the channel to the south of the Island. Hydraulic computations indicate that a cut 1600 feet in width through Galop Island with bottom at Elevation 214 flanked by dikes to eliminate cross-currents would provide a navigation channel which would meet the requirements of limiting velocities substantially as in the Recommended Plan. Although far more costly than the latter plan, it is believed to have sufficient advantages to navigation to justify its inclusion in this report as a possible alternate to the Recommended Plan, should model tests indicate unsatisfactory navigation conditions with the Recommended Plan.

The Alternate Plan is shown on Drawing M-IA, and in greater detail in the folio entitled "Miscellaneous Features Plans," Drawing GC-R-1/1A. The hydraulic features of the plan are discussed in detail in Appendix A-2.

f. Discussion of Relative Merits of the Recommended and Alternate Plans. Both the Recommended and Alternate Plans reduce the loss of head sustained at Galop Island in the Original 238-242 Plan. In the Recommended Plan there is a gain in head at the powerhouse varying from 0.2 foot to 2.2 feet, according to the river discharges and the lake level at Lake Ontario, if and when the limitation of the powerhouse pool to Elevation 238 is removed. With the Alternate Plan this gain in head is from 0.2 foot to 2.6 feet.

In the Recommended Plan the 850-foot cut through Galop Island will be excavated in the dry behind a plug as in the Alternate Plan, but in order to excavate the navigation channel to the south of Galop Island

without disturbing the lake level, it will be necessary to close off this channel with cofferdams and remove the plug in the Galop Cut progressively as the south channel is closed off. This should cause no real difficulty in maintaining the Lake Ontario levels as the Galop Cut has a discharge capacity about equal to the unimproved south channel. After the Iroquois Dam has been completed, the cofferdams in the south navigation channel can be removed and the lake level controlled from the dam.

The Alternate Plan provides a simple plan of controlling lake levels in Lake Ontario during the construction period. At the present time, the control of Lake Ontario is at the head of Galop Island. In this plan a plug will be left at the head of the 1600-foot Galop Cut during construction. After the Iroquois Dam has been completed the plug can be removed and the lake level controlled by the operation of the dam.

In the Recommended Plan navigation follows the channel to the south of the Island. While this course is somewhat winding, it should not present any navigation difficulties of consequence. There are no sharp bends, the least radius being about 8000 feet. If found to be necessary, curvature of the entrances could be modified at a moderate increase in cost. In the Recommended Plan there is a possibility of providing an auxiliary navigation channel in the 850-foot cut through Galop Island by some dredging at the upper end and deepening in the cut. The estimated quantity of excavation for the Recommended Plan (for Feature No. 1) is 22,547,000 cubic yards at an estimated cost of $25,072,200.

The principal advantage of the Alternate Plan accrues to navigation. The 1600-foot cut through Galop Island provides a wide and practically straight navigation channel through the reach from Chimney Point to Lotus Island with adequate entrances at both ends. Cross currents are eliminated by dikes flanking the channel. The chief disadvantage of the plan is its excessive cost. The increase in width of the cut through Galop Island from 850 to 1600 feet involves a large increase in the amount of excavation, particularly at Galop Island where the widened portion passes through highest sections of the Island requiring cuts of 70 feet or more in depth. The total quantity of excavation for the Alternate Plan (for Feature No. 1) is 42,687,000 cubic yards at an estimated cost of $50,054,500.

Further details of the quantities and cost of excavation for Feature No. 1 and other features included under Channel Excavation, are given in Table 3 entitled "Quantities and Cost Estimates for Channel Excavation."

TABLE 3

QUANTITIES AND COST ESTIMATES FOR CHANNEL EXCAVATION

	Unit Price	Recommended Plan Quantity (c.y.)	Recommended Plan Amount	Alternate Plan Quantity (c.y.)	Alternate Plan Amount
		FEATURE NO. 1 - Mi. 67-74			
Cofferdam	Lump		$2,000,000		
Dry earth excavation	$0.50	13,255,000	6,627,500	16,655,000	$8,327,500
Dry rock excavation	1.70	1,591,000	2,704,700	4,597,000	7,814,900
Wet rock excavation	7.00	472,000	3,304,000	1,412,000	9,884,000
Dipper dredging	0.75	7,229,000	5,421,750	17,523,000	13,142,250
Hydraulic dredging	0.35	-	-	2,500,000	875,000
Totals		22,547,000	$20,057,950	42,687,000	$40,043,650
Engrg. & Contingencies			5,014,250		10,010,850
TOTAL COST OF FEATURE NO. 1			$25,072,200		$50,054,500
		FEATURE NO.3			
Dry earth excavation	0.50	7,614,000	$ 3,807,000	7,614,000	$ 3,807,000
Dipper Dredging	0.75	1,705,000	1,278,750	1,705,000	1,278,750
Totals		9,319,000	$ 5,085,750	9,319,000	$ 5,085,750
Engrg. & Contingencies			1,271,450		1,271,450
			6,357,200		$ 6,357,200
TOTAL COST FEATURE NO.3					
		FEATURE NO.9			
Dry earth excavation	0.50	5,916,000	$ 2,958,000	5,916,000	$ 2,958,000
Dry Rock excavation	1.70	100,000	170,000	100,000	170,000
Wet rock excavation	7.00	107,000	749,000	107,000	749,000
Dipper Dredging	0.75	4,867,000	3,650,250	4,867,000	3,650,250
TOTALS		10,990,000	$ 7,527,250	10,990,000	$ 7,527,250
Engrg. & Contingencies			1,881,750		1,881,750
TOTAL COST OF FEATURE NO.9			$ 9,409,000		$ 9,409,000
		FEATURE NO.33			
Dry earth excavation	0.50	1,865,000	$ 932,500	1,865,000	$ 932,500
Dipper dredging-ordinary	0.75	1,209,000	906,750	1,209,000	906,750
Dipper " swift water	1.05	3,632,000	3,813,600	3,632,000	3,813,600
Totals		6,706,000	$5,652,850	6,706,000	$5,652,850
Engrg. & Contingencies			1,413,150		1,413,150
TOTAL COST OF FEATURE NO.33			$7,066,000		$7,066,000
		FEATURE NO.34			
Dipper dredging-ordinary	$0.75	960,000	$ 720,000	960,000	$ 720,000
" " swift water	1.05	1,096,400	1,151,220	1,096,400	1,151,220
Totals		2,056,400	$1,871,220	2,056,400	$1,871,220
Engrg. & Contingenc.			467,780		467,780
TOTAL COST OF FEATURE NO.34			$2,339,000		$2,339,000

TABLE 3 (cont'd)

QUANTITIES AND COST ESTIMATES FOR CHANNEL EXCAVATION

SUMMARY

Feature No. 1	22,547,000	$25,072,200	42,687,000	$50,054,500
Feature No. 3	9,319,000	6,357,200	9,319,000	6,357,200
Feature No. 9	10,990,000	9,409,000	10,990,000	9,409,000
Feature No. 33	6,706,000	7,066,000	6,706,000	7,066,000
Feature No. 34	2,056,400	2,339,000	2,056,400	2,339,000
TOTALS	51,618,400	$50,243,400	71,758,400	$75,225,700

In summing up the relative advantages of the two plans, it appears that so far as the effect on power, there is little choice. During the construction period the Alternate Plan provides a simpler method of maintaining lake levels in Lake Ontario. The principal advantage of the Alternate Plan is that it appears to offer a superior navigation channel in the vicinity of Galop Island. The principal advantage of the Recommended Plan is its lower cost. Whether the advantages of the straighter 1600-foot channel of the Alternate Plan over the winding 600-foot channel to the south of Galop Island the potential channel through the 850-foot Galop Cut of the Recommended Plan are worth this extra cost involved cannot be determined until a model study is made to determine just how great the above advantages are. In this connection it may be stated that the computations of a flow divided into two or more channels are apt to be unreliable There is no rational solution. Assumptions have to be made for friction, cofferdams and diversion of flow and balanced by trial. The computed flow for the Recommended Plan is:

Canadian Channel	67,000 c.f.s.
Galop - 850' wide, bottom El. 216.0	119,000 c.f.s.
American (improved)	124,000 c.f.s.

For the Alternate Plan:

Canadian Channel	22,000 c.f.s.
Galop - 1600' wide, bottom elev. 214.0	230,000 c.f.s.
American (unimproved)	58,000 c.f.s.

It is desired to emphasize the importance of conducting comprehensive model tests to study and verify the hydraulic computation and to develop a satisfactory navigation channel in the vicinity of Galop before a definite plan is adopted.

Pending the results of model tests which have been authorized, the estimates of cost in this report are based on the Recommended Plan for Feature No. 1.

g. Present Status of Plans.- Contract plans and specifications

have not been prepared. Preliminary plans and estimates of cost have been made and various studies carried out for determination of the recommended solution. The additional preliminary work listed below should be completed before the final plans are prepared.

(1) All dimensions of the recommended Galop Channel were based on computations. These calculated dimensions will be verified by hydraulic model tests.

(2) Additional core borings are desirable to determine the quantity of ledge rock to be excavated and additional probings are necessary to determine the quantity of excavation which could be advantageously performed by hydraulic dredges.

(3) A detailed survey is required for the purpose of obtaining cross sections, profiles and subsurface data for use in preparation of contract plans and specifications.

h. Estimated Cost and Time Required to Complete Plans.- The hydraulic model tests for determining channel dimensions and dike locations will be made from data and maps now available. The verifications will be made at the U. S. Waterways Experiment Station, Vicksburg, Mississippi. The necessary additional subsurface explorations could be performed by four crews equipped with diamond drill rigs, two crews equipped with Highmark probing rigs and one seismic crew, in about 90 days during the navigation season beginning in April. Because of ice conditions prevailing in the river from December to April, it would not be advisable to undertake this work during the winter. Only the most urgent considerations would justify an attempt to drill or take soundings in the Galop Section of the river during the winter season. The detailed survey should be made while borings and probings are in progress. After the foregoing work is completed and results available, the time required for completing the plans and specifications will not exceed 30 days. The estimated cost of the additional preliminary work is as follows:

Hydraulic model study........................	$80,000
Subsurface exploration........................	52,000
Detailed Survey..............................	16,000
Preparation of Contract Plans and Specifications..............................	2,000
Total to complete preliminary work...	$150,000

i. Estimated Cost.- The estimated cost based on preliminary plans, and the surveys and subsurface investigations so far made is shown below. It is based on the construction program outlined in paragraph 34. Any change in that schedule may alter this estimate. A more detailed statement is contained in Appendix III-O(3)

Contract cost..................................	$20,057,950
Engineering and contingencies (about 25%)..	5,014,250
Total cost..........................	$25,072,200

36. FEATURE No. 2 - GALOP ISLAND ICE CRIBS.- a. Description and Purposes.- Three groups of ice cribs, located immediately upstream from Galop Island, are proposed. (See Plate M-1.) Each group will extend across the head of each of the three channels, including the proposed new cut through Galop Island. The cribs will be placed at intervals across the channels and will be connected by floating booms during the ice season. The purpose of orib and boom assemblies is; (1) to form an obstruction against which floating ioe and slush can pack to form an ice cover; and (2) to retain the ioe in place in the spring until it rots and melts. For reasons set forth in paragraph 34d(1), D priority has been assigned.

b. Treatment Under the Original 238-242 Plan.- Barriers of the same general type were included in the Original 238-242 Plan. Three groups of cribs, one across the head of each of the three ohannels of the Galop Island section similar to those now recommended are shown on Plate M-II. It was proposed to space the oribs about 300 feet, center to center, in locations where velocities of flow are relatively high, and from 500 to 700 feet, oenter to center, across navigation channels or at locations where velocities are relatively low. Details of design of the proposed cribs or the method of placing are not available.

c. Additional Data Secured.- Other than the recent more comprehensive soundings, no additional data has been secured and no work has been done on the design for these structures by the St. Lawrence River District. However, the proposed new layout of the Galop Island cuts will require relocation of at least some of the cribs. It is believed that the same general plan as indicated in the Original 238-242 Plan will be satisfactory.

d. Discussion.- The hydraulio model tests of the Galop Island reach of the river to be made in conjunction with the final design of the channels and structures therein should include the river for a sufficient distance upstream to permit studies and observations of the flow and velocities, for use in the final layout and design of the ice cribs. These tests will not interfere with the progress of the work, because the Galop Island ice oribs need not be constructed until some time subsequent to work on the Galop Island cuts. Only a small portion of the cost of the hydraulic model studies should be charged to this feature and the cost of preparing the plans would be small.

e. Estimated Cost.- The cost as taken from the Engineering Estimate June 1941, is as follows:

Contraot Cost, from Estimate of June 1941	$410,000
Engineering and Contingenoies (about 25%)	104,000
Total Cost...........................	$514,000

37. FEATURE NO.3 - CHANNEL WORK, MILE 74 to MILE 76.5 - SPARROWHAWK POINT CUT AND TOUSSAINTS ISLAND CUT.- a. Description and Purpose - The construction of a new ohannel through the Sparrowhawk Point and Toussaints Island Section of the river from Mile 74 to Mile 76.5 is neoessary

in the interests of both power development and deep water navigation through the International Rapids Section of the St. Lawrence River. The work should be done without interruption to existing navigation. Extensive changes in the existing river channel are essential to meet these requirements. The outlines of the recommended channel enlargement are shown on Drawing CC-R-1/1, Appendix III-O(1). The work will involve removal of approximately 9,000,000 cubic yards of material. For reasons set forth in paragraphs 34b(2) and 34c(1), P-1 and P-2 priorities have been assigned.

b. Treatment Under the Original 238-242 Plan.- Under the Original 238-242 Plan, a large portion of Sparrowhawk Point was to be removed to elevation 205 and a channel was to be cut through Toussaints Island to elevation 205 for enlargement of the cross section for hydraulic purposes. Further enlargement of the channel was to be obtained by removing a portion of the Point known as Presque' Isle and by removing the bank of the existing Galop Canal on the river side. A navigation channel was proposed through these deep cuts. Since the bottom elevation necessary for navigation in this reach is only 214, sufficient depths for navigation would exist in the cuts designed for hydraulic purposes.

c. Additional Data Secured.- Recent and more comprehensive soundings by the United States Lake Survey together with additional surveys and subsurface investigations made by this District, provided more detailed data for design than was available to engineers formerly concerned with this problem. Consideration of the design in the light of the more complete data resulted in various modifications in the original plan. A complete description of the methods and results of the subsurface investigations is contained under "Subsurface Investigations for Navigation Channels and Hydraulic Cuts" in Appendix III-O(3).

d. Discussion. - The Original 238-242 Plan providing for removal of Sparrowhawk Point, deepening of the river in front of this point, and a deep cut through Toussaints Island, together with other subsidiary channel enlargements, is basically correct. Studies of the new data and comparison of alternate plans for enlarging the river channel have led to the conclusion that improved navigation conditions and a simplified construction program can be obtained by cutting through Sparrowhawk and by removing the southerly portion of Toussaints Island. The construction program will be simplified because of a reduction in the volume of difficult dipper dredging. With the exception of a minor channel enlargement at the tip of Sparrowhawk Point, allother subsidiary channel enlargements can be omitted under the proposed plan. Initial excavation of the channel to full width and depth is necessary in order to reduce the velocity of the water to the stipulated maximum of 2.25 feet per second. Any sacrifice of width or depth to obtain a provisional channel will result in velocities higher than 2.25 feet per second and will tend to prevent the formation of a fixed ice cover, thus defeat one of the principal purposes of the channel enlargement. Furthermore, the construction of a provisional channel of lesser dimensions than ulti-

mately required with a view to future enlargement, will result in greater unit prices for the deferred work because of the character of the excavation and the necessity for different construction methods after the pool is raised.

e. Recommended Plan. - The plan now recommended is shown on Plate M-1 and Drawing QC-R-1/1, Appendix III-0(1). Since no advantage will result from the improvement of the channel through Sparrowhawk Point without the proposed channel through Toussaints Island, all work should be performed under one contract. Furthermore, the construction period should be kept to a minimum so that the temporary inconvenience to existing down-bound 14-foot navigation resulting from new, sudden turns, or other obstructions in the stream during construction, will be of short duration. In view of these requirements, the following construction program is proposed:

(1) Construction of dikes or cofferdams to include as much as possible of the Sparrowhawk Point cut to be followed by the excavation in the dry.

(2) Similar procedure for the Toussaints Island cut.

(3) Control of the river at the Iroquois Dam, opening of the dikes and routing of the river through the new cuts. To be accomplished upon completion of the dry excavation and without disturbing the regimen of the stream.

(4) Removal of portions of the dikes by dry methods followed by excavation with dipper dredges after creation of the pool at suitable levels and reduction of velocities.

f. Present Status of Plans.- Contract plans and specifications have not been prepared. Preliminary plans and estimates of cost have been made and various studies carried out for determination of the recommended solution. The additional preliminary work listed below should be completed before the final plans are prepared.

(1) All dimensions of the recommended channel were based on computations. These calculated dimensions should be verified by hydraulic model tests. The model studies should be included under Feature No. 1.

(2) Additional test borings are required to determine the character of the material to be excavated and to establish the side slopes of the cut.

(3) A detailed survey is necessary for the purpose of obtaining cross-sections, profiles and underground data.

g. Estimated Cost and Time Required to Complete Plans.- The necessary model studies could be completed within 60 days by an established hydraulic laboratory. The necessary data for the model test is available. The necessary subsurface explorations could be made by two crews

equipped with diamond drill rigs in about two months, during the navigation season. The exploration of the land area of Sparrowhawk Point is entirely feasible during the winter, but the exploration of the water areas and of Toussaints Island during the winter is very hazardous because of floating ice and ice jams, and is not recommended unless urgently required. Detailed surveys should be made while the borings are in progress. When the foregoing work is completed and results available, the time required to complete the plans and specifications will not exceed 20 days. Estimated cost of the foregoing preliminary work is as follows:

Subsurface Exploration	$4,000	
Location Survey	3,000	
Preparation of Contract Plans and Specs.	1,000	
Total Cost of Completing Preliminary Work..............................		$8,000

h. Estimated Cost.- The estimated cost, based on preliminary plans and surveys and subsurface investigations so far made and in accord with the construction program outlined in paragraph 34, is shown below. A more detailed statement is contained in Appendix III-O(3)

Contract Cost..........................	$5,085,750
Engineering and Contingencies (about 25%)...............	1,271,450
Total cost........................	$6,357,200

38. FEATURE NO. 4 - IROQUOIS DAM AND DIKES. - a. Description and Purpose. - The work includes the Iroquois Dam and the shore section at each end thereof. The dam is a buttressed, concrete gravity structure consisting of 40 gate openings with their sills at mean elevation of river bottom, flanked by concrete gravity non-overflow sections, with earth wing dams extending to high ground at each end. The dam extends from the south mainland near Rockway Point in a northwesterly direction to Iroquois Point on the Canadian side of the river, which is confined to one channel only at the locality. The Transverse Mercator coordinates of the ends of the spillway at the axis of the dam are; easterly end, North 1,760,785.9, East 249,563.9, and westerly end, North 1,760,-785.9, East 247,086.1. The purpose of this dam is to control the flow of the river, especially during the winter season when formation of a solid ice sheet can be expedited by partially closing the gates. For reasons set forth in paragraph 34b (3), P-1 priority has been assigned.

b. Treatment Under the Original 238-242 Plan. - The Original 238-242 Plan included a shorter control dam located a short distance downstream from the present planned location. The exact location and details of construction are not available, but the estimates indicate that the structure would have been designed to serve the same purpose as now proposed. It was intended to sink caissons to bedrock and place gates between the caissons without the use of cofferdams. This plan was fully investigated and found to have various disadvantages including construc-

tion difficulties. The Joint Advisory Boards recommended the substitution of a structure of more conventional type built within cofferdams.

c. Additional Data Secured. - The subsurface explorations, carried out by this District have furnished information supplementing that available at the time of the Original 238-242 Plan. This additional information suggested certain changes in the original plan, as discussed below.

d. Discussion. - Studies of channel hydraulics showed that it would be advantageous to relocate this dam upstream from the original location in order to secure a larger channel area and therefore a lower stream velocity, which would be conducive to formation of a fixed ice sheet. The maintenance of conditions which favor the formation of a continuous ice sheet over the greater portion of the water surface upstream is one of the most important functions of the proposed dam. Since the bedrock drops slightly in an upstream direction and since the length of the crossing is increased, the upstream relocation of the dam will increase the cost of the structure. However, it is imperative that the hydraulic requirements be met and the relocation proposed is believed to be the most economical for a dam which will properly satisfy these hydraulic requirements. The plans propose construction of cofferdams and dewatering the site in order to insure the construction of a dam capable of resisting the most severe combination of head and ice pressure which could occur under the design criteria. (See Chapter II, Paragraph 22b.) Under the Original 238-242 Plan, the dam was designed for a static head of only a few feet, but further studies and considerations indicate that the design head should be increased. In particular, it may be desirable for this dam to maintain project level upstream while the pool created by the Long Sault Dam is lowered, at times of subsidence or signs of weakness in the earth dikes retaining the lower pool. Accordingly, the design head was assumed at 19 feet or 14 feet plus ice pressure. Studies show that the caisson type of construction would cost almost as much as open cofferdam methods. It is believed that more satisfactory foundations could be obtained by the latter method of construction. Except for the fact that it is a more elaborate and substantial structure, the Iroquois Dam as proposed does not differ materially from that included in the Original 238-242 Plan.

e. Recommended Plan. - The Iroquois Dam is a buttressed, gravity structure having a maximum height of 118 feet. The center line is the arc of a circle having a radius of 1,700 feet. There are 40 gate openings 50 feet wide, extending down to a continuous concrete sill at elevation 200.0, which is approximately river bottom. This spillway section, with an overall length of 2,390 feet, is flanked at each end by a concrete gravity bulkhead 193 feet long with a short earth fill wing dam completing the shore tie at each end. The overall length of the masonry section is 2,776 feet, and that of the entire structure is 3,600 feet. The 40 openings between piers contain 32 two-section fixed wheel, vertical lift gates and 8 single-section gates of the same type, operated by two travelling gantry cranes. The latter gates, four at each end of the spillway, rest on concrete stop-logs which are placed in the lower half of these end openings. The top of the gates is at elevation 248. Piers

10 feet thick at axis of the dam form the buttresses and support the deck structure. The gate deck will support the gantry tracks and a concrete highway, and will provide for a future railroad track.

f. Present Status of Plans and Specifications. - The contract plans, specifications, and design analysis for Iroquois Dam have been completed and comprise Appendices III-4(1), (2), and (3). The general plans and specifications are complete and could be used as a basis for award of contracts for the construction of the dam and its flanking earth dikes. Plans and specifications for the purchase of the gates, the two gantry cranes, and all structural and reinforcing steel have been prepared and are included in Appendix III-4(2), Part 2. As the Iroquois Dam could probably be built in two years or less, the specifications cover all materials and equipment. The specifications as included in the aforementioned appendix include only the technical requirements for the various materials and equipment as the general sections are subject to frequent changes.

g. Estimated Cost and Time Required to Complete Plans. - As stated in preceding paragraphs, it is believed that the plans and specifications are sufficiently complete to permit advertisement for bids as soon as construction is authorized. Supplementary information could be obtained at small cost and additional details supplied as the work progresses without delaying project construction schedules.

h. Estimated Cost. - The summary of estimated costs for the Iroquois Dam, including the cost of that portion of the Point Rockway Canal (Feature No. 7) above Mile 79, is given below. Detailed estimates of the cost of the general construction contract and of the materials and equipment to be furnished by the Government are contained in Appendix III-4(3).

Contract Cost	$7,956,482
Materials and Equipment furnished by the Government	5,650,660
	$ 13,607,142
Engineering and Contingencies (about 18%)	2,449,858
Total Cost..........................	$ 16,057,000

39. FEATURE NO. 5 - ALTERATION OF LOCK 25 AND ATTACHED DIKES.- a. Description and Purpose.- Lock 25, located at Iroquois, Ontario, is a masonry structure located at the downstream end of the present Galop Canal. The present coping of the lock is at elevation 245, which is not sufficient for conditions which will exist after the creation of the proposed pool, and it is proposed to alter the lock to conform with new water levels. It will be necessary to raise and extend the flanking dikes so as to form an extension of the Iroquois Dam to high land on the Canadian side of the river. For reasons set forth in paragraph 34c(2), this work has been assigned P-2 priority.

b. Treatment Under the Original 238-242 Plan. - The treatment of Lock 25 and dikes as proposed under the Original 238-242 Plan has

been adopted in its entirety because this lock is and will remain Canadian property, and because it has been impractical in the time available to study the plan in detail. The Canadian estimate was used without alteration for the same reasons.

c. Additional Data Secured. - No additional data has been secured. It is believed that the necessary surveys and explorations could be carried out and the complete plans prepared in 3 to 6 months, at an estimated cost of approximately $25,000.

d. Estimated Cost. - The estimated cost as taken from the Engineering Report of January 1941 is given below. No new estimate has been prepared by this District.

Contract Cost, from report of January 1941	$ 482,220
Engineering and Contingencies (about 25%)	121,780
Total Cost.............................	$604,000

40. FEATURE NO. 6 - REHABILITATION OF IROQUOIS, ONTARIO.- The town of Iroquois, Ontario located on the Canadian side of the St. Lawrence River opposite Mile 78 has a population of approximately 937. Practically the entire town will be inundated or damaged after creation of the pool at final stage, and extensive rehabilitation measures will be necessary. Under the provisions of the International Agreement, the Canadian Government will handle all rehabilitation work in Canada. The estimate of cost contained in the Engineering Report of January 1941 includes an item of $3,379,000 for rehabilitation of Iroquois. At the request of the Canadian authorities, no study of the problem was made by the St. Lawrence River District and no recommendations are presented. The work should be accomplished during the early stages of the project construction program so as to be completed before the pool is raised sufficiently to affect the town. The estimated cost as taken from the Engineering Report of January 1941 is given below. No new estimate has been prepared by this District.

Contract Cost, from report of January 1941	$3,004,270
Engineering and Contingencies (about 12½%)	374,730
Total Cost.............................	$3,379,000

41. FEATURE NO. 7 - POINT ROCKWAY CANAL AND APPROACH CHANNELS.-

a. Description and Purpose. - A canal across Rockway Point is necessary for passage of 27-foot navigation around the Iroquois Dam which will cross the river from Iroquois Point to the United States shore. A low lift lock in the canal will be necessary because of the head which will exist at the dam and the slope of the backwater around Point Rockway. The proposed location of the feature is in a natural depression, which is probably an old river channel extending across Point Rockway as shown on Plate M-1. The plans for both the canal and lock have been developed in accordance with the criteria for navigation channels as

stated in paragraph 22c. Two short wing dikes, one extending in a northwesterly direction and the other in a southeasterly direction from the upstream ends of the lock walls are necessary in order to prevent the water of the pool above the dam from flowing through the natural depression in which the canal is located. Work is required for navigation purposes only. Operations are included in the contracts for Iroquois Dam and Point Rockway Lock and P-1 priority, to correspond with those features, has been assigned.

b. Treatment Under the Original 238-242 Plan. - The Original 238-242 Plan contemplated a canal for the same purpose varying in width from 442 feet to 292 feet and located in the natural depression across Point Rockway. Extensive dikes parallel with and located close to the canal were provided for in the plans. Bottom elevation of the canal above and below the lock was planned at 214 and 209 feet, respectively. Topographic limitations required a bend of about 30 degrees in the canal to provide adequate entrances and to avoid excessive excavation. The lock was located below this bend. The location of the canal as proposed in the original plan is basically correct.

c. Additional Data Secured. - A detailed survey for this canal was made by this office and numerous borings, probings, and seismic tests were taken and recorded on the drawings contained in Appendix B-1 and B-2. These subsurface explorations disclosed the presence of previously unknown ledge rock above grade. Alternate locations were, therefore, investigated but none was found to be more satisfactory than the original location.

d. Discussion.- Since the Original 238-242 Plan is basically correct, only minor changes are recommended. Spoil banks or dikes should not be located close to the canal bank because of a soft clay formation which overlies ledge rock in this locality and is inadequate for their support. Since elimination of the dikes would result in submergence of both banks of the canal, a bottom width of 442 feet throughout has been provided in accordance with criteria in paragraph 22c. Also the alignment of the canal will satisfy the straight line criterion referred to in paragraph 22c. Because of severe cross currents at the entrances, the approach channels have been flared to provide easier and safer access. With respect to location of the lock, detailed investigation supports the conclusion that a lock below the bend is preferable to one above. In the interest of economy, it is desirable to utilize the large amount of ledge rock, which will be excavated from the canal above Mile 79, as a source of concrete aggregate, for cofferdam fill and as protection stone in the construction of the Iroquois Dam. This rock is of satisfactory quality, and the amount to be removed will be more than adequate to supply all needs. Therefore, the plans and specifications for the construction of the canal from Mile 76.5 to Mile 79 have been incorporated with those for the Iroquois Dam. (See Drawings QD-1-190/1 to 14, Appendix III-4(1).) It is also in the interest of economy to utilize the ledge rock present in the canal below Mile 79 for similar purposes in building the lock and wing dikes. Since the priorities for this

portion of the canal and the lock are identical, the plans for the canal from Mile 79 to Mile 81 have been incorporated with those for the lock. Sacrifice of width or depth for early use of this canal is not recommended because of the construction difficulties and consequent additional cost which would result if a portion of the work is deferred. The construction program for the canal should be left to the discretion of the contractor for the dam, insofar as is possible without detriment to the work. It should be noted that the construction of the lock will be simplified and less costly if performed before the site is inundated by creation of the pool above the Long Sault Dam.

e. Present Status of Plans. - Plans and specifications for the canal have been prepared to the extent given below. The proposed location of the canal is shown on Drawing QC-R-1/2, Appendix III-O(1).

(1) Contract drawings and specifications for the canal from its upper entrance at Mile 76.5 to the bend in the canal near Mile 79, have been incorporated with those for the Iroquois Dam. (Appendices III-4(1) and (2).)

(2) Contract drawings and specifications for the canal from the bend at Mile 79 to its lower entrance at Mile 81 are included with those for the Point Rockway Lock. (Appendices III-8(1) and (2).)

(3) Analysis of Design for the entire canal. (Appendices III-4(3) Part II and III-8(3).)

(4) Detailed surveys have been completed.

(5) All subsurface explorations necessary for the preparation of contract drawings have been made.

(6) Detailed computations of excavation quantities have been made.

(7) Advertisement for bids immediately after final approval of the existing plans and specifications will be possible, and no further expenditures for preliminary work will be required.

f. Estimated Cost. - The estimated cost of excavation of Point Rockway Canal from the point of beginning at the upper entrance, to the upstream end of the upper guide wall of Point Rockway Lock is approximately $4,523,000. This estimate is based on the assumption that the canal excavation will be included in the contracts for Iroquois Dam (Feature No.4) and Point Rockway Lock (Feature No.8). In the complete new project estimate summarized in paragraph 76 of Chapter IV, approximately 62 per cent and 38 per cent of the estimated cost of this canal have been included in the estimates for the dam and the lock, respectively, the canal not appearing as a separate item in this estimate.

42. FEATURE NO. 8 - POINT ROCKWAY LOCK AND ATTACHED DIKES. -

a. Description and Purpose. - The location and general layout

of Point Rockway Lock and Canal are shown on Drawing QC-R-1/2 in Appendix III-O(1) and on Plate M-1. The purpose of these structures is to carry navigation around the proposed Iroquois Dam. The lift in the lock will range normally between 1 and 5 feet. The lock chamber is 80 feet in width, 800 feet in length, and the minimum depth over the sills is 30 feet. Wing dikes are provided on each side of the lock, extending to high ground on each side of the natural depression in which the canal is located. These dikes supplement Iroquois Dam in preventing by-passing of the pool water around the lock. In addition, they afford a convenient and economical location for an access highway to the south abutment of the dam and the area between the canal and the river (see paragraph 55g). The downstream approach to the lock will be excavated to provide suitable depth and alignment for navigation. For reasons given in paragraph 34b (4), P-1 priority has been assigned.

b. Treatment Under the Original 238-242 Plan. - The Original 238-242 Plan contemplated a canal with one lock in practically the same location and for the same purpose as now proposed. The governing dimensions are the same. Minor changes in location and design were made.

c. Discussion. - The proposed lock is about 1,000 feet downstream from the location indicated in the Original 238-242 Plan. This proposed site is further downstream from the bend in the canal and thus will improve the upper approach to the lock. Investigations indicated that foundation and other conditions are equally satisfactory at the original and proposed sites. The lift and general dimensions of the proposed lock are as contemplated in the Original 238-242 Plan. Sector gates were adopted in lieu of miter gates because the former can be operated against flowing water or static head and can be safely used for filling and emptying the chamber under the low heads that will exist at this lock. Use of sector gates also eliminates the necessity for a guard gate and a separate system of culverts and valves for filling and emptying the lock chamber, and permits the normal use of one, instead of the two, gates at each end of the lock with resultant savings in annual maintenance and operating costs. The lock and approach walls and gate and emergency dam sills were designed as concrete gravity sections founded on ledge rock. Two pairs of sector gates are provided at each end of the lock chamber to assure continuous service. Because of the small lift, it is economical to construct the upper gates to the same height and design as the lower gates. The sector gates are protected by wire rope fenders of the type used at the Welland Canal Locks. Four such fenders are provided, one above and one below each of the two gate bays. An emergency or lock-unwatering dam is provided at each end of the lock chamber, outside of the sector gates. These dams consist of steel stop-log units equipped with end rollers, which span the lock walls. They are moved by a fixed stiff-leg derrick mounted on the wall at each end of the lock. The approach guide walls extend 1,200 feet beyond each end of the lock and flare away from the entrances sufficiently to permit mooring of one vessel of maximum length, without interfering with the clearway for a vessel emerging from the lock. A bobtail, through truss, swing bridge is provided across the upper end of the lock in connection with the access highway to Iroquois Dam and the area between the canal and the river; the bridge will also provide for possible future railroad traffic. (See Drawing QL-1-185/1,

2 and 3, Appendix III-8(1).) The wire rope fenders, emergency dams, the swing bridge, other operating equipment, all fixed metal and other details, where practicable, are similar to the corresponding features for the proposed Robinson Bay and Grass River Locks. Earth dikes extend to high ground on each side of the lock to complete the dam across the valley in which the canal and lock are located. These dikes will be constructed of suitable materials from the lock and canal excavation or from borrow areas at adjacent till ridges. For design of the section of canal above the lock and a discussion of the proposed location and layout of the canal and dikes, see paragraph 41d.

d. Present Status of Plans and Specifications. - Detailed plans, specifications and analysis of design for Point Rockway Lock and Dikes, the lower approach, and the canal below Station 159 + 50 are contained in Appendix III-8(1), (2) and (3). Plans, specifications and analysis of design for the canal above Station 159 + 50 are included in Appendix III-4(1), (2) and (3). Lock drawings show the principal features of the work required, but are incomplete as to detail. Masonry drawings show only the principal dimensions and layout of structures. No reinforcing steel details are shown. Overall dimensions and type of main members are shown for the sector gates and other important steel structures, but details of secondary members, connections, etc., are not given. Illustrations for gate machinery and other mechanical parts, and major castings are included and described where practicable, but are not detailed. It is believed that the drawings and specifications are sufficiently complete for the purpose of advertisement for bids. Plans and specifications and analysis of design for the bridge are included with the lock. The bridge plans give limiting dimensions only; it is contemplated that a complete design for the bridge and bridge operating machinery will be made by the contractor. The bridge is supported by the lock walls, which are designed to carry the added load, and thus no additional substructure work is required. The analysis of design for the lock is not complete, but refers in many instances to the proposed Robinson Bay Lock, which covers in detail many design features common to both locks. The Analysis of Design for Iroquois Dam, Part II, also supplements the Point Rockway Lock Analysis for design features of the canal. Prior to advertisement, it would be desirable to take additional probings and drill auger holes along the dike foundations, to check the profiles of the clay and the underlying sand and gravel. It would also be desirable to obtain undisturbed samples of the clay in the dike foundations for shear tests. A few test pits should be excavated to explore the extent and character of till in prospective borrow areas at adjacent ridges.

e. Estimated Cost and Time Required to Complete the Plans. - The aforementioned explorations and tests could be completed in about one month at an estimated cost of about $1,000, without delaying prosecution of the work. Supplemental drawings for the lock structure will be necessary prior to or during construction, covering mainly the additional details required for construction of the masonry, reinforcing steel, structural steel items and miscellaneous metal parts. As many of these drawings as possible should be prepared to supplement the existing drawings prior to advertisement for bids. It is estimated that the additional drawings could be completed in approximately one month at an estimated cost of $2,000.

f. Estimated Cost. - A summary of the estimated cost is given below. Detailed estimates are contained in Appendix III-8(3). As stated in paragraph 41f, a portion of the cost of the Point Rockway Canal (Feature No. 7) is included in this estimate.

Contract Cost....................	$5,379,713
Materials and Equipment furnished by the Government............	836,500
	$6,216,213
Engineering and Contingencies (about 18%)..................	1,134,787
Total Cost...............	$7,351,000

43. FEATURE NO. 9 - RIVER WORK BETWEEN POINT THREE POINTS AND CANADA ISLAND.- a. Description and Purpose.- The following work is included:

- Point Three Points North Cut
- Point Three Points South Cut
- Leishmans Point Cut
- Ogden Island West Cut
- Little River Cut
- Waddington Cut
- Ogden Island Middle Cut
- Ogden Island East Cut
- Removal of Morrisburg Canal Dike
- Canada Island Cut

Channel enlargement through the reach of the river from Miles 79.5 to 85 is necessary to satisfy the requirements for winter operation of the power plant and to provide suitable navigable depths. This work should be accomplished with minimum inconvenience to existing navigation through the open river, the Morrisburg Canal or at Lock 25 at the entrance to the Galop Canal. The outlines of the proposed channel enlargements are shown on Drawing WC-R-1/1, Appendix III-O(1), and Plate M-1. For reasons given in paragraphs 34c (4), (5) and (6), P-2 priority has been assigned.

b. Treatment Under the Original 238-242 Plan. - The following items for improvement of this portion of the river were included in the Original 238-242 Plan as shown on Plate M-II.

- Point Three Points North Cut, Grade ≁ 200
- Point Three Points, South Cut, Grade ≁ 200
- Leishmans Point Cut, Grade ≁ 215
- Leishmans Point South Cut, Grade ≁ 220
- Leishmans Point North Cut, Grade ≁ 210
- Ogden Island West Cut, Grade ≁ 210
- Ogden Island Middle Cut, Grade ≁ 210
- Ogden Island East Cut, Grade ≁ 208
- Little River North Cut and Little River South Cut, Grade ≁215
- Cut Across Ogden Island, Grade ≁ 213
- Waddington Cut, Grade ≁ 210
- Ogden Island East Cut in Little River, Grade ≁ 210
- Morrisburg Canal Dike Removal, Grades ≁ 208, ≁ 215 and ≁ 235
- Canada Island Cut, Grade ≁ 208

These channel enlargements were designed to provide mean velocities or 2.25 feet per second to insure formation of a winter ice cover. The proposed navigation course as shown on Plate M-II passes through the Ogden

Island West, Middle, and East Cuts, a portion of the Morrisburg Canal Dike Removal and the Canada Island Cut. In order to satisfy the hydraulic requirements, the grades in some of these cuts were lower than required for navigation, (+ 210.5)

c. Additional Data Secured.- Recent and more comprehensive soundings by the United States Lake Survey together with additional surveys and subsurface investigations by the St. Lawrence River District resulted in various modifications in the details of the original plan. A description of the subsurface investigations conducted since 1940 is contained under "Subsurface Investigation for Navigation Channels and Hydraulic Cuts" in Appendix III-O(3).

d. Discussion. - The original plan is basically correct. From study of the additional data now available, it is concluded that substitution of the following cuts for those of the original plan will result in improved navigation courses, and will be more economical. See Drawing WC-R-1/1, Appendix III-O(1).

Point Three Points North Cut, Grade + 200
Point Three Points South Cut, Grade + 200
Leishmans Point Cut, Grade + 210
Ogden Island West Cut, Grade + 210
Ogden Island Middle Cut, Grade + 210
Ogden Island East Cut, Grade + 210
Little River Cut, Grade + 215
Waddington Cut, Grade + 210
Canada Island Cut, Grade + 210
Morrisburg Canal Dike Removal, Grade + 208

The proposed cuts provide sufficient cross sectional area for a mean velocity of flow not exceeding 2.25 feet per second as required for formation of an ice cover.

e. Recommended Plan. - The recommended plan is shown on Drawing WC-R-1/1, Appendix III-O(1) and Plate M-1. The following construction program is proposed:

(1) Construct dikes or cofferdams in relatively shallow water to include as much as possible of Point Three Points North and South Cuts, and Ogden Island, West, Middle and East Cuts followed by excavation in the dry of these cuts.

(2) Upon completion of the dry excavation, remove as much of the cofferdams around Ogden Island Cuts as possible without disturbing water levels in the Morrisburg Canal, then suspend operations until the pool above the Long Sault Dam is raised sufficiently to reduce the currents in this reach.

(3) After creation of the pool, complete these cuts by dipper dredging.

(4) Construct a cofferdam across the head of Little River

connecting with low dikes in front of Leishmans Point Cut and Ogden Island West Cut, and the necessary cofferdam downstream from Waddington Cut, followed by excavation in the dry of Leishmans Point Cut, Little River Cut and Waddington Cut as one job.

(5) Upon completion of all work possible in the dry, suspend operations until the pool is raised, then complete these cuts by dipper dredging.

(6) Defer the removal of Morrisburg Canal Dike and Canada Island Cut until the pool has been raised sufficiently to permit up-bound 14-foot navigation to use the open river, then perform the work by dipper dredging.

f. Present Status of Plans.- Contract plans and specifications have not been prepared. Preliminary plans, estimates of cost and various studies have been made for determination of the recommended solution. The additional preliminary work listed below should be completed before final plans and specifications are prepared.

(1) Hydraulic model tests of the recommended channel to verify computed dimensions.

(2) Additional subsurface exploration by drilling, probing and seismic methods, to determine the character of the material to be excavated and elevation of the rock surface in the proposed cuts.

(3) A detailed survey for the purpose of obtaining cross-sections, profiles, and underground data.

g. Estimated Cost and Time Required to Complete Plans.- The necessary model studies could be completed within 60 days by an established hydraulic laboratory. The necessary data for the model tests are available. The required subsurface explorations could be made by one seismic crew, one probing crew and three core drilling crews in about two months during the winter season and about one month during the navigation season. During the winter season all land areas concerned are accessible. Drilling in the Rapids Plat during the winter is very hazardous because of floating ice and ice jams, and it is not recommended unless urgently required. Detailed surveys should be made while the borings are in progress. When the foregoing work is completed and the results available, the time required to complete the plans and specifications will not exceed 20 days. The estimated cost of the foregoing preliminary work and preparation of the plans and specifications is as follows:

Hydraulic Model Study	$15,000
Subsurface Exploration	5,000
Detailed Survey	12,000
Preparation of Contract Plans and Specifications	1,000
Total Cost of Completing Preliminary Work	$33,000

h. Estimated Cost.- The estimated cost based on preliminary

plans and surveys and subsurface investigations so far made is shown below. This is based on the construction program outlined in paragraph 34. A more detailed estimate is contained in Appendix III-O(3).

Contract Cost......................................	$7,527,250
Engineering and Contingencies (about 25%)..	1,881,750
Total cost..................................	$9,409,000

44. FEATURE NO. 10 - REHABILITATION OF WADDINGTON, N. Y.-

a. Description and Purpose.- Waddington, N. Y., population 671, is located on Route No. 37 between Massena and Ogdensburg on the south bank of the St. Lawrence River opposite Mile 84. The work to be performed consists of acquisition of property, and possible relocation of some utilities at the east and the west ends of the main street along the river. A milk station and highway bridge on Route No. 37 near the mouth of Big Sucker Brook, and the Norwood and St. Lawrence Railroad terminal and dock in the vicinity will be inundated. For reasons set forth in paragraph 34c(3), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The cost of work for rehabilitation of the village has been included in the Original 238-242 Plan under the general heading "Acquisition of Land", but no details of construction or rehabilitation measures were given.

c. Discussion.- A study of the problem has not been made and no plan has been formulated. Relocation of the Norwood and St. Lawrence Railroad terminal is discussed under Feature No. 13. The milk station must be relocated on higher ground. Route No. 37 will be relocated to bypass Waddington to the south. Relocation or abandonment of the highway bridge over Big Sucker Brook on Route No. 37 at the east end of town is discussed under Feature No. 12. A topographic survey of the vicinity has been made by this office and is shown on Drawings Nos. WS-1-511/9 and 10, Appendix III-O(1). Additional surveys will be required to locate the taking line, to determine the extent of property damage, and to secure data on utilities. Subsurface exploration may be necessary to determine the effect of higher levels on existing foundations. Acquisition of property for proposed relocations will be necessary. After completion of the surveys, plans will probably be required for relocation of utilities. These surveys and plans will not delay construction work since they can be completed prior to the end of the second stage of construction.

d. Estimated Cost and Time Required to Complete Plans.- It is estimated that the preliminary work will require three months and will cost about $ 5,000.

e. Estimated Cost.- Since no separate study has been made, the cost is included in Feature No. 37, Acquisition of Land and Easements in the United States.

45. FEATURE NO. 11 - REHABILITATION OF MORRISBURG, ONTARIO.-

The town of Morrisburg, Ontario, located on the Canadian side of the St. Lawrence River opposite Mile 85 has a population of approximately 1,420. A substantial portion of the town will be inundated or damaged after creation of the pool at final stage and extensive rehabilitation measures will be necessary. Under the provisions of the International Agreement, the Canadian Government will handle all rehabilitation work in Canada. At the request of the Canadian authorities, no study of the problem was made by the St. Lawrence River District and no recommendations are presented. The work should be accomplished during the early stages of the project construction program so as to be completed before the pool is raised sufficiently to affect the town. The estimate of cost contained in the Engineering Report of January 1941 includes an item of $5,024,000 for the rehabilitation of Morrisburg as follows:

Contract Cost, from report of January 1941.......	$4,465,310
Engineering and Contingencies (about 12½%).......	558,690
Total Cost......................	$5,024,000

46. FEATURE NO. 12 - RELOCATION OF UNITED STATES HIGHWAYS BETWEEN WADDINGTON AND MASSENA, N.Y.- a. Description and Purpose.- Portions of New York State Highway Routes 37 and 37B between Massena and Waddington will be flooded after the pool is raised to operating level. It is proposed to relocate the flooded sections. For reasons set forth in paragraph 34c(7), work has been assigned P-2 priority.

b. Treatment under the Original 238-242 Plan.- The 238-242 Plan provided for relocation or reconstruction of these highways, but few details of the plan are available.

c. Discussion.- The proposed relocation of Route 37B is shorter than that under the Original 238-242 Plan. It involves locating the Richards Landing dike north of Route 37B, except near Massena Canal Intake, and moving Bradford Point dike westward so as to permit use of the existing road as the connection between Route 37B and Route 37. (See Plate M-1.) The proposed relocation of Route 37 between Coles Creek and Waddington involves an entirely new alignment from that under the Original 238-242 Plan. Surveys and cost estimates of various locations south of the existing road disclosed that relocation of the road further south will be less expensive than its reconstruction in the present location.

d. Relocation of Route 37B.- The recommended plan for relocation of route 37B is shown on Drawing No. LHN-1-1/1, Appendix III-O (1). The westerly portion of relocated highway consists of the existing road beginning at Route 37 and running along Bradford Point Dike to the northerly end thereof. It will then continue for a distance of about 7 miles along new and existing roads to Richards Point. Construction of about 5 miles of new roads is involved. The highway will consist of a bituminous macadam pavement, 22 feet in width and 6-foot shoulders. No bridges will be required.

e. Relocation of Route 37.- The recommended plan for relocation of Route 37 is shown on Drawings Nos. WHN-1-1/3-8, Appendix III-O(1). The relocated highway will start at a point just south of Waddington on

Route 345 and continue for about 6 miles to a junction with the existing Route 37 east of Coles Creek. The highway will be of construction similar to the relocated Route 37B described above. Typical sections and details are shown on Drawing WHN-1-1/2, Appendix III-O(1). Bridges will be required at the crossings over little Sucker Brook, Brandy Brook, and Coles Creek. Two plate girder bridges now installed on the abandoned part of the present road are available. Standard New York State Highway Specifications for roads of this class will be used. Geological reconnaissance and explorations for the purpose of determining overburden conditions at the bridge sites and at high fills between Coles Creek and Route No. 345 have been completed. The explorations consisted of test pits and auger holes, and drilling one hole in overburden. The locations and records of the explorations are shown on Drawing WHN-1-2/1, Appendix III-O(1).

f. Bridge Site at Coles Creek.- The explorations disclosed that the overburden at the Coles Creek site consists of silty sand for depths up to 5 feet underlain by compact silty and gravelly sand. At the site of the abutments, the overburden consists of compact silty and gravelly sand. It is considered that little difficulty will be experienced in obtaining suitable foundations for the bridges and that side slopes of 1 on 1½ for fill will be satisfactory.

g. Fill Sites on Tributaries of Coles Creek.- Explorations showed that the overburden in the tributary located 1,000 feet southwest of Coles Creek is firm material and that side slopes of 1 on 1½ for fill are satisfactory at this location. The overburden in the tributary 2,500 feet southwest of the Coles Creek bridge site consists of soft clay to a depth of at least 12 feet, and side slopes of 1 on 3 for fill are required in this area.

h. Bridge Site at Brandy Brook.- Test pits and auger holes showed that the overburden at the sites of abutments consists of firm material, generally a silty, gravelly sand. The hill which rises above the northeast abutment consists entirely of compact fine to medium sand.

i. Bridge Site at Little Sucker Brook.- A test pit at the Little Sucker Brook site disclosed silty sand and gravel 3.0 feet below the ground surface, indicating firm material.

j. Present Status of Preliminary Work.- The preliminary work performed in connection with Route 37 consists of a field survey, subsurface explorations and determination of slope and allowable loading on fills. Profiles of the route and detailed contour maps of bridge sites were made. Explorations include borings and test pits at sites of all bridges and high fills. Results of probing are shown on Drawing WHN-1-2/1, Appendix III-O(1). Additional cross sections will be required along the new location to determine quantities of materials moved. Bridge relocations will require further study involving design of a new bridge and design of abutments for relocated girders of two bridges. No field work was performed in connection with the relocation of Route 37B. A plan and profile were plotted from existing contour maps. A field survey will be necessary to obtain the alignment, a profile, and cross sections for estimating quantities.

Subsequent to the field survey, the plan and profile map should be revised and complete contract drawings prepared. This work should be coordinated with field work relating to adjacent dikes. Subsurface explorations will also be required for determination of highway foundation. Drawings pertaining to this feature are included in Appendix III-O(1), and an analysis of design is presented in Appendix III-O(3).

k. Estimated Cost and Time Required to Complete Plans.- It is estimated that additional field work will require one month, and will cost $1,500. The total cost of all additional preliminary engineering is estimated at $10,000. This work will not delay the construction program as it can be performed at any time before completion of the second stage of construction. It would be desirable to complete the foundation course in one working season and allow it to settle prior to placing the bottom and top courses the following season.

l. Estimated Cost.- The estimated cost is given below. A detailed estimate is contained in Appendix III-O(3).

Contract Cost....................................	$678,838
Engineering and Contingencies (about 25%).....	170,162
Total Cost	$849,000

47. FEATURE NO. 13 - RELOCATION OF NORWOOD AND ST. LAWRENCE RAILROAD. a. Description and Purpose.- The Norwood and St. Lawrence Railroad Company operates a single track line from Norwood, New York, where it connects with the St. Lawrence Division of the New York Central to Waddington, New York. A limited amount of freight and passenger traffic is handled over this railroad, which is about 18 miles long. The Waddington terminal is on the St.Lawrence River at the mouth of Big Sucker Brook and includes a dock for the interchange of pulp wood. The dock, station, and a portion of the track will be flooded by the pool created during the third stage of construction. The railroad bridges across Little Sucker Brook and Brandy Brook will also be flooded. For reasons set forth in paragraph 34c(7), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan proposed relocation of the terminal to a point upstream from Waddington at which deep water for navigation would be available after creation of the pool. It was proposed to begin the railroad diversion east of Brandy Brook and bypass Waddington. New railroad bridges would be required across Brandy Brook, Little Sucker Brook, and Big Sucker Brook.

c. Discussion.- The railroad interests prefer to retain the terminal at approximately the present location, but at a higher elevation. Deep water will be available when the pool is created. Preliminary studies indicate that materials will be saved by this plan. The length of the new track required will be considerably less, but a new dock will be required in either case. Preliminary studies indicate that the two existing bridges over Brandy Brook and Big Sucker Brook could be raised under this plan, while three new bridges would be required under the original relocation plan. However, this matter requires further study. A construction railroad spur line will probably be required in connection with the

proposed work at Iroquois Dam and Point Rockway Lock. A portion of this spur line can be located so as to serve as part of the proposed permanent relocation.

d. Proposed Plan.- The plan now proposed provides for maintaining the existing alignment and raising the tracks from a point about 700 feet west of Brandy Brook to a point about 200 feet east of Little Sucker Brook, and thence approaching the new dock from the east rather than from the southwest as at present. This plan involves raising the bridges at Brandy Brook and Little Sucker Brook, the construction of a new dock about ½ mile downstream from the present location and the construction of a new depot. A sketch showing a feasible plan and profile is shown on Drawing No. WRR-R-1/1, Appendix III-O(1).

e. Present Status of Plans.- Contract plans have not been prepared. A topographic survey of the general locality was made. Detailed surveys will be required in connection with the two bridges to be raised, the site of the new railway station and new dock, and to determine the profile of the proposed relocations. Subsurface explorations at the various construction sites will be required.

f. Estimated Cost and Time Required to Complete Plans.- Since it will be necessary to relocate the railroad, etc., prior to creation of the pool during the third stage of construction, the surveys and subsurface explorations, and preparation of contract drawings and specifications must be completed during the first or second stage of construction. The work will require three months and is estimated to cost $6,000.

g. Estimated Cost.- The cost as taken from the Engineering Estimate of June 1941 is given below. No new estimates have been prepared by this District.

Contract Cost, from Estimate of June 1941.......	$209,000
Engineering and Contingencies (about 25%).......	52,000
Total Cost..........................	$261,000

48. FEATURE NO. 14 - DIKES ON UNITED STATES SIDE BETWEEN WADDINGTON AND CROIL ISLAND.- a. Description and Purpose.- The proposed Coles Creek, Bradford Point, and Louisville Landing dikes are located from one-half to two miles inland from the St. Lawrence River between Miles 89 and 96. See Drawing LE-A1-2/1, Appendix III-O(1). The dikes are required to prevent overflow of pool water into Grass River. The Coles Creek Dike extends across a flat, sandy marsh and terminates on higher ground on either side. The Bradford Point Dike and Louisville Landing Dike No. 3 extend between two glacial till ridges and cross a wide valley. The Louisville Landing Dikes Nos. 1, 4, and 5 are small dikes on firm material between high points. For reasons set forth in paragraph 34c(8), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- Similar dikes were included in the Original 238-242 Plan. Additional subsurface data indicate that slight changes in the locations are advisable for

economic reasons. Therefore, the Bradford Point Dike has been moved to the west side of the adjacent highway to preserve the existing road, and the former Louisville Landing Dikes Nos. 2 and 3 have been combined into one dike at the location of the proposed Dike No. 3.

c. Discussion. - The subsurface explorations indicate that in the valleys at both the Bradford Point Dike and Louisville Landing Dike No. 3, the overburden consists of soft clay overlain by 10 to 20 feet of loose, uniform, silty sand. The Coles Creek Dike has a freeboard averaging 5 feet, with 20-foot top width and slopes of 1 on 1½. Riprap will not be necessary because this dike will be protected against wave action by the land in front, the elevation of which is generally above the ordinary operating level of the pool. The Bradford Point Dike and the Louisville Landing Dikes are as follows: (1) top width, 35 feet, (2) upstream and downstream slope, 1 on 3 and 1 on 2½, respectively, (3) the upstream slope will be protected by heavy riprap, (4) fill will be compacted earth, and (5) a cut-off trench and a drainage trench will be provided where the height is greater than 10 feet. These dikes obstruct the natural drainage of the swamp land located to the landward and drainage works will be required for the natural runoff and seepage of pool water through the dikes or their foundations. This drainage system is discussed under Feature No. 15. Earth fill for all dikes can be obtained in the immediate vicinity. However, it will be necessary to obtain heavy riprap, sand and gravel filter, and backing materials from more distant sources. Light riprap can probably be obtained from stones in the earth fill.

d. Present Status of Plans.- Detailed plans have not been prepared. Geological reconnaissance has been undertaken at the sites of Coles Creek Dike and Louisville Landing Dikes Nos. 1, 4 and 5. At the sites of Bradford Point Dike and Louisville Landing Dike No. 3, test borings in the overburden were made, and seismic exploration was made to determine bedrock elevations. Before final design can be completed, detailed surveys and additional exploration will be required. The location of all explorations completed and the records of the drilling are shown on Drawing LE-A1-2/1, Appendix III-O(1). Quantity and cost estimates were made for each of the dikes.

e. Estimated Cost and Time Required to Complete Plans.- It is estimated that 4,000 man hours will be required to complete the engineering investigation and prepare contract plans and specifications at a cost of $10,000. This work should be scheduled so that the dikes can be completed before the pool is raised to operating levels.

f. Estimated Cost.- The estimated cost is shown below. A detailed estimate is contained in Appendix III-O(3).

Contract Cost...................................	$587,950
Engineering and Contingencies (about 25%).....	147,050
Total Cost...............	$735,000

49. FEATURE NO. 15 - MASSENA CANAL INTAKE WORKS INCLUDING RICHARDS LANDING DIKE.- a. Description and Purpose.- The Massena Power Canal

is the property of the St. Lawrence River Power Company, a subsidiary of the Aluminum Company of America. It has a length of about 3 miles and extends in a southeasterly direction from the St. Lawrence River at the upper end of South Sault channel to a powerhouse on the north bank of Grass River. The head at the powerhouse is about 43 feet. A permit has been granted by the War Department for the use of 25,000 second-feet of water, from which about 80,000 horsepower can be developed. During severe winters, ice in the canal causes a considerable reduction in discharge, head and power. The power is used solely for the manufacture of aluminum. In order to assure uninterrupted production during the construction of the proposed St. Lawrence project, certain control works at the canal intake are required. Those intake works consist of a central spillway or gate structure of reinforced concrete flanked by bulkheads of mass concrete embedded in flanking earth wing dams. They will be constructed at the head of the present power canal and across a cut-off connecting the river and the power canal. The Mercator Coordinates of the structure are as follows:

End of north bulkhead at dam axis -	N.	1,808,491.06
	E.	345,976.37
End of south bulkhead at dam axis -	N.	1,807,888.94
	E.	345,753.63

The Richards Landing Dike is an earth structure extending about 2 miles upstream from the intake works. It will extend from the west end of the south wing dam of the intake works upstream to high ground. Drainage will be required for the low areas lying landward from the dike. Materials for construction of the dike can be obtained from the till ridges in the vicinity. The required riprap can be obtained from boulders embedded in the earth material. No sand and gravel fill or backing material will be required. For reasons set forth in paragraph 34b(5), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a similar structure, but no detailed plans are available. It was described as a weir, probably consisting of a series of full depth openings controlled by vertical lift or sector gates. The method of diversion through a bypass or cutoff canal was the same as that now proposed; however, the original structure was centered on the old canal instead of on the cutoff canal as in the proposed plan. The sections used for all earth dikes have been modified in accordance with foundation conditions as determined by additional investigations.

c. Additional Data Secured.- Several borings, probings, and seismic explorations of the site and soil analyses have been made. New data regarding the effect of ice on a structure of this type are available.

d. Discussion. With a given quantity of water, production of power at the proposed Barnhart Island development will be twice as much as with the Massena Power Canal. It is therefore obvious that when the demand at the Barnhart Island Powerhouse becomes great enough to use the entire flow of the river, some arrangement will probably be made to termi-

nate the water rights of the St. Lawrence River Power Company and supply the Aluminum Company with power from Barnhart Island. However, during the later stages of the construction of the proposed project the increased pool level at the canal intake will put the Massena plant out of business as a power producer some months before the production of power will become possible at Barnhart Island. Since interruption of the production of aluminum is undesirable, it will be necessary to install control works at the head of the canal which will permit operation continuously during the construction period. The proposed change in location of the permanent canal intake structure from that shown in the Original 238-242 Plan will make possible construction in the dry before creation of the pool. Bottom outlet gates will be used to keep the discharge surfaces completely submerged at all times. This will eliminate freezing and also require a minimum amount of gate movement for regulation of flow because the gates will always have considerable head of water and a small adjustment will cause large flow fluctuations. Because there is no spillway between the intake works and the powerhouse at the Aluminum plant, the works are designed so that the canal can be automatically maintained at its present or other desired level regardless of variations in demand and in river elevations. Although the design of the structure itself is practically complete, study will be required during the construction of the works in cooperation with the Aluminum Company regarding the serious operating problems involved. Modification of the two existing wasteway sluices at the powerhouse or possibly the provision of a rather expensive spillway at the lower end of the canal may be necessary.

e. Recommended Plan.- The plan recommended consists of a partly reinforced concrete outlet structure flanked by earth wing dams. The concrete structure will be built on the center line of a short diversion or cutoff canal which will be excavated immediately south of the present canal above the existing highway bridge. This diversion canal will serve as the permanent waterway after the structure is completed and the present canal will be closed by the new north wing dam. The gate house or spillway will be equipped with eight 9-foot by 14-foot tractor gates operated by individual electric hoists. Stop-log slots will be placed upstream and downstream from each gate and provision will be made for installation of trashracks in the upstream slots. The deck will carry a roadway and an overhead traveling gantry crane. The dam will be approximately 100 feet high above the rock foundation and 642 feet long from end to end of the concrete bulkheads which will be joined to the earth wing dams. The wing dams will be of compacted earth protected on the upstream side with riprap and on the downstream side with rock and gravel drains. The intake works will maintain constantly regulated flow at all stages of the St. Lawrence River from present stage up to final pool elevation, irrespective of the powerhouse demand. This will be accomplished during the diversion period by manually operated stop-logs later supplemented by two of the permanent tractor gates operated by their fixed hoists, and during the final closure of Long Sault Dam by use of all the tractor gates. The tractor gates will be operated automatically through float wells, located at the intake structure and at the powerhouse and electrically connected to the individual gate hoists.

f. Present Status of Plans and Specifications.- The general plans, specifications, and design analysis for the Massena Canal Intake Works have been completed and comprise Appendices III-15(1), (2), and (3). Contracts for the construction of the structure including the flanking earth dikes can be consummated. The plans and specifications provide only for erection of the gates, electrical conduits, and operating machinery, including the traveling crane. Plans and specifications for the purchase of the gates, gate hoists, crane, and the electrical equipment, have not been prepared although the principal features of all of this equipment have been so defined by the design analysis and shown on the drawings that the contract plans and specifications can be readily prepared. Soil conditions under the south wing dam will require further study before construction. A thorough hydraulic model study should be made with special attention to the design of the stilling basin and to operation of the headworks and canal. These studies should be initiated shortly after the general contract for the structure is let so that any necessary changes may be made before the gates are fabricated. In connection with the Richards Landing Dike, it will be necessary to make surveys and economic studies of the property damage involved at various locations in order to determine its exact location and design. Explorations to date, consisting of 8 drill holes, indicate that the overburden is generally a clay overlain by 5 to 10 feet of loose uniform silty sand; however, buried till hills may rise almost to the ground surface beneath this alluvial blanket. The location of all explorations and the records of the drilling are shown on Drawings DW-A-2/1 and DW-1-1/4, Appendix B-1. Quantity and cost estimates for the dike have been made. It is estimated that all of the unfinished work described above will cost approximately $25,000 including the cost of the hydraulic model studies. The model tests can be made in three months.

g. Estimated Cost.- The summary of estimated costs is given below. A detailed estimate of cost for the Intake Works is contained in Appendix III-15(3).

(1) Intake Works

Contract Cost......................	$2,413,317	
Materials and Equipment furnished by Government.........	925,255	
	$3,338,572	
Engineering and Contingencies (about 18%)....................	601,428	
Total Cost............		$3,940,000

(2) Richards Landing Dike

Contract Cost......................	$1,195,650	
Engineering and Contingencies (about 25%).....................	298,350	
Total Cost............		1,494,000
Grand Total......................		$5,434,000

50. FEATURE NO. 16 - LONG SAULT CANAL INCLUDING DIKES NOS. 1, 3, 5 AND 6 AND THE DOWNSTREAM APPROACH CHANNEL.- a. Description and Purpose.- The construction of a ship canal around the Long Sault Dam and the Barnhart Island powerhouse is necessary to provide deep draft navigation through this section. Two locks, having a maximum combined lift of approximately 90 feet, are required to overcome the difference in levels created by the dam and powerhouse. Because of topographical features, it is advisable to locate the lower lock near the mouth of Grass River and the upper one near Robinson Bay. The topography is adapted to an intermediate pool, with surface elevation approximately 200 feet, thus making the lift at the locks nearly equal. The location of the canal, locks and the entrance channels were planned to conform with the criteria stated in Chapter II. The recommended location and plan of the canal and locks appear on Plate M-I and Drawings SC-R-1/2 and LMC-R-1/1, Appendix III-0(1). For reasons set forth in paragraph 34b(6), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan. - The Original 238-242 Plan contemplated a canal having a width of 192 feet in its upper reaches and generally 292 feet in the remainder (see Plate M-II). Canal grade was established at 211.0 in the portion through the pool above Long Sault Dam, at 173.0 through the intermediate pool between the locks, and at 124.0 in the lower approach. Five structures in addition to the canal and system of dikes were proposed in the original plan, viz: (1) a guard gate above Robinson Bay Lock; (2) Robinson Bay Lock; (3) a supply weir for the intermediate pool below this lock; (4) a regulating weir for the intermediate pool; and (5) Grass River Lock. The alignment of the proposed canal was approximately as follows: beginning at a point in the river on the north side of Long Sault Island near Grassy Island; thence in a straight line across Long Sault Island, the South Channel and the United States mainland to a point immediately above Robinson Bay Lock where it turned about 30 degrees to the left; thence following the low lying areas to a point in the south channel at the mouth of Grass River. This alignment involved two bends and an extensive system of dikes located above Robinson Bay Lock to retain the pool of the Long Sault Dam. Dikes were also required to retain the intermediate pool at elevation 200.

c. Additional Data Secured.- A detailed survey and subsurface exploration were made throughout the length of the proposed canal. Special attention was given to the explorations at the lock sites for the determination of the best and most economical locations. The explorations disclosed the presence of numerous bodies of soft marine clay along the route of the canal and along proposed sites of dikes. Alternate locations for the canal, the locks, and all accessory dikes were investigated and the locations finally adopted were based on studies of all available data. A detailed description of the method used and results attained by the subsurface investigations are contained in the Analysis of Design for the Long Sault Canal, Appendix III-16(3).

d. Discussion. - Minor revisions in the original plan are considered advisable in view of the additional data and the application of the criteria for design presented in Chapter II, but no basic changes are proposed. The original grades of the canal have been slightly modified, but the locations of the structures are approximately the same.

Because of the existence of large bodies of soft marine clay of very low bearing power as disclosed by the subsurface explorations, it will be necessary to locate spoil banks and dikes at a considerable distance from the canal in order to prevent slides. The original plan proposed several dikes near the canal. As a result of locating the dikes at a distance from the canal, both banks will be submerged; consequently the bottom width of 442 feet prescribed in the design criteria for such conditions has been adopted in the proposed plan. The channel under the original plan through the pool above the upstream end of the canal contained several undesirable bends, particularly at the entrance to the canal and along the north side of Croil Island. Studies of alternate routes between Robinson Bay Lock and Weavers Point, Mile 92, indicate that it is preferable to adopt a direct route passing south of Cat and Croil Islands to Robinson Bay Lock, and to relocate the upper portion of the Long Sault Canal and the guard gate accordingly. In adopting this route, consideration was given to reduced costs resulting from use of the material excavated from the canal for construction of the necessary dikes. The locks are relocated slightly for the purpose of obtaining better foundations at higher elevations. The location of the canal between the locks is changed and straightened accordingly. The supply and regulating weirs proposed under the original plan are eliminated, as incorporation of these features in the locks was determined to be more economical and satisfactory. Because of the probable strong cross currents in the river below the entrance to the Grass River Lock and their effect in forcing vessels off their course, the downstream entrance to Grass River Lock has been given more flare than originally planned.

e. Recommended Plan.- The recommended plan, consisting of the revisions discussed in the preceding paragraph, is as shown on Plate M-1 and Drawings SC-R-1/2 and LMC-R-1/1, Appendix III-O(1). For purposes of reducing the cost and construction period, the following work schedule is proposed for the construction of the dikes connected with the canal, locks and guard gate: (1) Dikes Nos. 1, 3,5, and 6 in conjunction with the Long Sault Canal; (2) Dike No.2 in conjunction with the guard gate; (3) Dike No.4 in conjunction with Robinson Bay Lock; and (4) Dikes Nos.7 and 8 in conjunction with Grass River Lock. For similar reasons, it is necessary that the entire proposed canal to the upstream end of Grass River Lock be excavated in the dry and that Grass River Lock site with the lower approach be excavated in the wet. Should the deep draft navigation features of the project be deferred, it is desirable, in the interest of economy, that the upstream portion of the canal from Richards Point to Robinson Bay Lock be excavated before creation of the pool and that, insofar as possible, Dikes Nos. 1, 2, 3, and 4 be constructed with material excavated from this portion of the canal. Should this canal excavation be performed after creation of the pool, more costly work by a dipper dredge will be required.

f. Present Status of Plans and Specifications.- Plans and specifications have been prepared by this office. Some revision of the dike drawings and quantities may be required when the additional sub-surface explorations have been completed and analyzed. (See Appendix III-16(1) and (2).) Detailed surveys have been made. All subsurface explorations necessary for the preparation of contract drawings have been obtained. Additional investigations of dike foundations are required as described

in Appendix III-16(3), at an estimated cost of $50,000. Detailed computations of excavation quantities have been completed. An Analysis of Design has been prepared.

g. Estimated Cost.- A summary of the estimate of cost is given below. This includes the cost of the Robinson Creek Drainage Ditch (Feature No.19) but does not cover the cost of the locks, guard gate, excavation for the lock, and the lower entrance channel. A detailed estimate of cost is contained in Appendix III-16(3)

Contract Cost................................	$7,063,960
Engineering and Contingencies (about 18%)..	1,271,040
Total Cost..........	$8,335,000

51. FEATURE NO. 17 - LONG SAULT GUARD GATE AND DIKE NO. 2.-

a. Description and Purpose.- The Long Sault Guard Gate consists of two concrete walls 110 feet apart with a sector-type gate consisting of two leaves. Both approaches to the guard gate are provided with guide and wing walls similar to those provided at the locks in the canal. Dikes are provided on each side of the structure to retain the pool above Long Sault Dam. The general location and layout of the canal, locks and guard gate are shown on Plate No. M-I. The purpose of the guard gate is to prevent the flow of water from the upper pool, in the event of failure of the Robinson Bay Lock gates, Dike No. 3 or 4. The guard gate would insure maintenance of the pool above Long Sault Dam under such circumstances and would minimize the damages downstream. For reasons set forth in paragraph 34o(9), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan. - The Original 238-242 Plan included a similar structure located at a corresponding place in the canal and intended to serve the same purpose. A miter gate with horizontal clearance of 80 feet between walls was proposed. A weir was provided adjacent to the guard gate for passage of water for lockage purposes when the gate was closed.

c. Additional Data Secured.- Additional surveys of the site of the guard gate and considerable additional subsurface explorations were made.

d. Discussion.- The proposed site of the guard gate is on the side of a ridge about 7,000 feet west of the site of Robinson Bay Lock and about 5,500 feet east of the South Sault Channel. It is about 1,500 feet southwest of the site contemplated under the Original 238-242 Plan. This change in location was made necessary by the change in alignment of the Long Sault Canal. (See Feature No.16). The distance between the proposed site and Robinson Bay Lock is about the same as in the Original 238-242 Plan, but the approaches to the guard gate under the proposed plan are improved by the elimination of bends in the canal and the river channel. The navigation width through the guard gate structure has been changed from 80 feet, as contemplated in the Original 238-242 Plan, to 110 feet to increase the speed and safety of navigation. This change was recommended by the operating staff of the Welland Canal. A sector-type

gate which can be closed while water is flowing through the structure has been adopted in lieu of the miter gate contemplated in the original plan, to provide greater assurance against the possible loss of pool water. With a sector-type guard gate, it is feasible and safe to pass the water required for lockage purposes at Robinson Bay Lock through the navigation opening. A separate "safety weir" such as provided at the Welland Canal Guard Gate and contemplated in the Original 238-242 Plan, can thus be omitted with resulting reduced construction, operation and maintenance costs.

e. Recommended Plan.- The gate bay, approach walls, and the gate and emergency dam sills are designed as concrete gravity sections. Ledge rock at the site as determined by recent subsurface explorations is too deep for a direct foundation of the structures thereon. It is proposed to use steel bearing piles for support of the gate bay walls and sills to avoid possible movements of the blocks which would interfere with gate operation as a result of reversals in loading. The approach walls will be founded on the hard, compact till overburden. The sector-type gate will consist of two leaves, each 45.5 feet in height having a radius of approximately 67 feet and swung on a pintle and hinges fixed to the walls. The gate leaves will swing into recesses in the wall when in open position, allowing the full 110-foot width between walls for navigation. Because of the long span, each gate leaf will be supported by rollers attached underneath at three points near the outer curved face and running on a metal track embedded in the sill and floor concrete. The gates will be operated by strut-and-sector type machines, similar to those proposed for the Robinson Bay Lock miter gates, and are designed to open or close the gates in 1½ minutes with no pressure or in about 4 minutes with the maximum possible hydrostatic pressure (43-foot head) on the leaves. The moving parts of these machines are interchangeable with the miter-gate machines at Robinson Bay Lock. The elevation of gate and emergency dam sills is such as to provide at least 30-foot depth of water over the sills when the pool is at the minimum stage expected during the navigation season. A guide wall, 1,200 feet long is provided in each approach to the structure. It is flared sufficiently to permit mooring a vessel of maximum length without infringing on the clearway of the guard gate. These walls are similar to the approach walls provided for locks. Two emergency or unwatering dams are provided, one at each end of the guard gate structure; each dam consisting of a number of steel stop-logs to be handled by a fixed stiff-leg derrick mounted on one wall. The stop-logs are equipped with end rollers to permit their installation under flow conditions if required. The stop-logs and derricks are generally similar to those at the locks, but somewhat larger because of the greater span. Wire rope fenders, similar to those for the locks, are also provided upstream and downstream from the guard gate to prevent damage from boats. The operating machinery and fender parts are interchangeable with corresponding parts at the three locks of the proposed project. The fenders can be omitted at the guard gate if the adopted plan of operation provides for the guard gate to be kept continuously open except during tests or emergency closures. A small culvert equipped with a sluice gate is provided in each wall of the guard gate structure for the passage of water required to replace leakage, seepage, and evaporation losses from the pool between the guard gate and Robinson

Bay Lock during periods when the guard gate emergency dams are in place. Dike No. 2 extends from the north guard gate wall to high ground in the ridge connecting with the south abutment of Long Sault Dam. A closure section of Dike No. 1 extends from the south guard gate wall to main Dike No. 1. The latter is included in the Long Sault Canal work. Dike No. 2 and the closure dikes are required to complete the barrier system for retaining the main pool and are designed in accordance with the criteria described elsewhere in this report. They will be constructed of suitable materials from foundation excavations for the guard gate and from borrow in adjacent till ridges and spoil dumps.

f. Present Status of Plans and Specifications. - Plans, Specifications and Analysis of Design for the Guard Gate and appurtenant dikes are contained in Appendix III-17(1), (2), and (3). The plans show the principal features of the work, but are incomplete as to detail. Masonry drawings show only the principal dimensions and layout of structures. No details for reinforcing steel are shown. Overall dimensions and the type of main members are shown for the sector gate and other important steel structures, but details of secondary members, connections, etc., are not given. Illustrations for gate machinery and other mechanical parts and major castings are included and described where practicable as to size, material, required performance, commercial type (where applicable), etc., but not detailed. It is considered that the drawings and specifications are sufficiently complete for the purpose of advertisement for bids. Prior to advertisement, however, it would be desirable to supplement the present data by additional subsurface exploration in the proposed borrow area in the ridge at the north end of Dike No. 2. One additional hole should be drilled in the clay foundation area of Dike No. 2 to obtain samples for shear testing.

g. Estimated Cost and Time Required to Complete Plans.- The additional explorations and the tests mentioned above, are estimated to cost about $2,500 and require about one month. They will not delay prosecution of the work. Supplemental drawings covering mainly the additional details required for concrete masonry, reinforcing steel, structural steel items and miscellaneous metal parts, etc., will be required prior to or during construction. As many of them as possible should be prepared to supplement the existing drawings prior to advertisement for bids.

h. Estimated Cost.- A summary of the estimated cost is given below. A detailed statement is contained in Appendix III-17(3).

Contract Cost	$1,838,898
Materials and Equipment furnished by Government	697,945
	$2,536,843
Engineering and Contingencies (about 18%)	460,157
Total Cost	$2,997,000

52. FEATURE NO. 18 - ROBINSON BAY LOCK AND ATTACHED DIKES.-

a. Description and Purpose.- Robinson Bay Lock is the upper of the two locks required for the Long Sault Canal. Plate M-1, and the Drawings in Appendix III-18(1) show the location and general plan. This lock is necessary, in conjuction with Grass River Lock (Feature No.20), for the purpose of overcoming the difference in elevation of approximately 85 feet which will exist under normal operating conditions between the water surface at the downstream entrance to the Long Sault Canal and in the pool above Long Sault Dam. The lock chamber is 80 feet in width, and 800 feet in length. The lift ranges from 38 to 42 feet under normal operating conditions with provisions for greater lifts under extreme conditions. Dike No.4 on the north side connects the upper end of the lock with the high ridge extending to the south abutment of Long Sault Dam. The closure section of Dike No.3 is included with this lock and the rest is included under Feature No. 16. These dikes are required to complete the barrier system necessary for maintaining navigation pool above Robinson Bay Lock, and incidentally provide a suitable location for the permanent access railroad and highway to Long Sault Dam and the Barnhart Island Powerhouse. A bobtail, through truss, swing bridge for combined railroad and highway traffic will span the upper end of the lock. This bridge is a duplicate of the proposed bridges across Grass River Lock and Point Rockway Lock. For reasons set forth in paragraph 34b(7), this work has been assigned P-1 priority.

b. Treatment under the Original 238-242 Plan.- A lock of this general type and size in the same general location was included in the Original 238-242 Plan. Adjoining it was a weir with gates to supply water to the intermediate pool between the two locks.

c. Additional Data Secured.- Considerable additional subsurface explorations and surveys pertaining to this feature were made. Similar work in connection with the Long Sault Canal (Feature No. 16), Grass River Lock (Feature No.20), and Long Sault Canal Guard Gate (Feature No. 17), have an indirect bearing on this work because of the interrelationship between these structures. Details are contained in the Analyses of Design for the corresponding features.

d. Discussion.- The proposed site is at a point in the ridge just north of Robinson Creek, about 5,000 feet southwest of Robinson Bay. It is about 750 feet north of the site in the Original 238-242 Plan. The change in location was made as the result of modifications in the location and alignment of the Long Sault Canal (see Feature No. 16) and the additional subsurface explorations by this office which indicated ledge rock at somewhat higher and more favorable elevations at the new site. The lift and general dimensions of the lock are the same as contemplated in the original plan, but it is not known whether a drawbridge was contemplated. A lower pool supply system is incorporated in the lock structure instead of the separate supply weir structure contemplated in the original plan. Detailed studies indicated that this modification will be feasible and desirable and will effect a saving in cost.

e. Recommended Plan.- The recommended plan, consisting of the revisions to the original plan discussed in the preceding paragraph, is shown on Plate M-1 and the Drawings in Appendix III-18(1). All lock and approach walls were designed as concrete gravity sections. The lock chamber walls are founded on ledge rock. The approach walls are founded partly on the hard compact till and partly on steel bearing piles. The sills for the lock gates and the emergency dams are founded on rock and are designed as concrete arches, thrusting against the lock chamber walls. The arch designs were used for economy, because of the considerable height of the sills above ledge rock. Lock gates are of the miter type, horizontally-framed and plated on both sides. Two gates are provided at each end of the lock chamber to assure safety and continuity of service. Combined emergency and lock unwatering dams are provided at each end of the lock chamber, outside the miter gates. These dams comprise steel stop-log units spanning the lock walls and equipped with end rollers. Fixed stiff-leg derricks on the lock walls provide means for moving the stop-logs. Wire rope fenders of the type used at the Welland Canal locks are proposed for protection of the miter gates against impact of ships. Side wall culverts are provided for filling and emptying the locks. They will have segmental type valves and the ports will be distributed along the entire length of the lock chamber. A guide wall 1,200 feet long is provided in each approach to the lock. The walls are flared sufficiently to permit mooring a vessel of maximum length without infringing on the clearway of the lock. A swing bridge is provided across the upper end of the lock for the permanent railroad and highway leading to Long Sault Dam and the area north of Long Sault Canal. The lower pool supply system was designed to discharge enough water into the pool so that with the maximum probable difference in lock lifts and the most adverse succession of up and downbound vessels, the drawdown in the pool will be negligible (estimated at about 0.2 of a foot). This system is equipped with a valve to provide control of the flow as required for pool level maintenance without waste of water. Dike No. 4 and the closure section of Dike No. 3 are required to complete the dike barrier system between Long Sault Guard Gate and Robinson Bay Lock, and are designed in accordance with the criteria established for other dikes in the Long Sault Canal system (see paragraph 22). These dikes afford a convenient and economical location for the proposed railroad and highway.

f. Present Status of Plans and Specifications. - Plans, Specifications and Analysis of Design for Robinson Bay Lock, with appurtenant structures are contained in Appendix No. III-18(1), (2), and (3). The plans for the lock are not complete as to detail. Masonry dimensions are generally complete. No details for reinforcing steel are shown. Overall dimensions and the type of principal members are shown for miter gates and other important steel structures, but details of secondary members, connections, etc., are not given. Illustration for gate machinery, valve machinery, and other mechanical parts are included and described, where possible, as to size, material, performance, commercial type, etc., but are not detailed. Because of the interchangeability of like machinery parts for the three deep-draft locks and the guard gate structure included in the project, it is proposed to purchase the following machinery in addition to that required for Robinson Bay Lock, under the Robinson Bay Lock contract, gate machines for Grass River Lock and Long Sault Guard Gate;

segmental valve machines for Grass River Lock; and wire rope fender machines for Grass River Lock, Point Rockway Lock and Long Sault Guard Gate. This procedure will result in minimizing the number of spare parts required and increasing the efficiency of maintenance and operation. It is considered that the drawings and specifications are sufficiently complete for the purpose of advertisement for bids. The plans, specifications and analysis of design for the drawbridge are included with those for the lock. The bridge plans give limiting dimensions only, and it is contemplated that a completed design for the bridge and bridge operating machinery will be made by the contractor. The bridge is supported by the lock walls, which were designed to carry the added load, and thus no additional work is required for the substructure of this bridge.

g. Estimated Cost and Time Required to Complete Plans.- Prior to commencement of construction, it would be desirable to supplement the present data by additional drilling to determine more fully the elevation of the rock surface throughout the length of the lock chamber walls and for some distance upstream and to explore the underlying strata at several points within the site area. This investigation might reveal that some economies could be realized by relocating the site upstream or downstream along the axis of the canal and would give additional assurance against the possibility of encountering foundation conditions materially different from that indicated by the present data. It is estimated that the additional drilling could be done in one to two months at a cost of about $4,000. If undertaken prior to or during the period of advertisement, it need not delay the construction schedule. A hydraulic model study to check the theoretical performance of the lock filling and emptying system and to determine the best size, shape, number and spacing of ports would be desirable. This study could be made at an established laboratory in two to three months, at a probable cost of about $6,000, half of which would be properly chargeable to Robinson Bay Lock and half to Grass River Lock. This study could be made after award of contract and during the early construction stages, without delaying construction schedules. Supplemental drawings covering details not shown on the drawings in Appendix III-18(1) should be furnished the contractor during construction. Such drawings should include the details of reinforcing steel, structural steel items, miscellaneous metal parts, and machinery and castings. As many of them as possible should be prepared prior to advertisement for bids.

h. Estimated Cost.- A summary of the estimated cost is shown below. A detailed estimate is contained in appendix III-18(3).

Contract Cost	$ 7,886,697
Materials and Equipment furnished by Government	2,603,275
	$10,489,972
Engineering and Contingencies (about 18%)	1,904,028
Total Cost	$12,394,000

53. FEATURE NO. 19 - ROBINSON CREEK DRAINAGE DITCH.- a. Description and Purpose.- This work comprises a ditch to carry the natural

runoff from a small area south of the Long Sault Canal in the vicinity of the proposed guard gate, which runoff will be obstructed by Dikes Nos. 1 and 3. The ditch will divert the runoff into Robinson Creek to the south. It should be completed at the same time as the aforementioned dikes. For reasons set forth in paragraph 34b(6), P-1 priority has been assigned.

b. Discussion.- No surveys have been made relating to this item as it is of relatively minor importance. A survey will be required to establish the most economical location and grade and contract drawings will then be prepared. One month will be sufficient to complete the engineering at an estimated cost of $1,000. It is considered advisable to delay this work until final plans for dikes, spoil areas, etc., in this vicinity are completed. It is proposed to include this and other drainage ditches which may be required because of the construction of Long Sault Canal in the contract for that canal.

c. Estimated Cost.- The engineering report of January 1941 contained an item of $6,630 plus 25% as the estimated cost. No further studies or estimates have been made. The cost is included in that of the Long Sault Canal (Feature No. 16).

54. FEATURE NO. 20 - GRASS RIVER LOCK AND ATTACHED DIKES.- a. Description and Purpose.- Grass River Lock is the lower of the two locks required for the Long Sault Canal. Plate M-1 and the drawings in Appendix III-20(1) show the location and general plan. It is necessary for the same purpose as the Robinson Bay Lock, and its dimensions are the same. (See paragraph 52a.) The lift ranges from 43 to 46 feet under normal operating conditions with provision for greater lifts under extreme conditions. Dike No. 8 connects the upper end of the lock with high ground on the north side of the canal, and Dike No. 7 connects it with high ground on the south side. These dikes are necessary for the maintenance of the intermediate pool in order to provide navigable depths in the canal between Grass River and Robinson Bay Locks. Incidentally, they will afford a convenient and economical location for the relocated Ottawa Branch of the New York Central Railroad and the highway from Rooseveltown to Cornwall, Ontario (see Feature No. 35). A bobtail, through truss, swing bridge for combined railroad and highway traffic will span the upper end of the lock. Excavation of the approach channels is also included with the lock. The upper approach will connect with Long Sault Canal (Feature No. 16) and the lower approach with the access channel from the St. Lawrence River, thus affording a through channel for deep draft navigation. For reasons set forth in paragraph 34b(8), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- A lock of similar size and type located in low ground about 2,000 feet west of the mouth of Grass River, was proposed in the Original 238-242 Plan. The relocated Ottawa Branch of the New York Central Railroad was shown as crossing the downstream end of the lock.

c. Additional Data Secured.- Considerable additional subsurface explorations and surveys pertaining to this feature were made. Similar

work in connection with the Long Sault Canal (Feature No. 16), the Robinson Bay Lock (Feature No. 18), and the Long Sault Canal Guard Gate (Feature No. 17) have an indirect bearing on this work because of their inter-relationship. Details are contained in the Analyses of Design for the corresponding features.

d. Discussion.- The location proposed for the lock is about 1,000 feet west and 300 to 400 feet south of the site indicated in the Original 238-242 Plan. The changes in location were made as a result of studies of the additional data. The westerly relocation was made primarily to provide for the flat side slopes of excavations necessary for stability of the natural earth barrier (consisting of soft, wet, marine clay of low shear strength) which would be left in place between Grass River and the deep excavation required for the lock wall foundations. The southerly relocation was made to place the lock foundations on the highest ledge rock revealed by the subsurface explorations. The proposed lift and general dimensions of the lock are the same as in the Original 238-242 Plan. A pool regulation system for discharging excess water from the navigation pool above the lock is incorporated in the lock structure, instead of a separate weir in the dike near Robinson Bay as contemplated in the original plan. Detailed studies indicated that this modification will be feasible and less costly.

e. Recommended Plan.- The recommended plan, consisting of the revisions to the original plan discussed in the preceding paragraph, is as shown on Plate M-1 and the Drawings in Appendix III-20(1). The lock chamber walls are designed as concrete gravity sections founded on ledge rock. The upper approach walls are also designed as concrete gravity sections, a portion of which are founded on hard, compact till and the remainder on steel bearing piles. The lower approach walls are of a type adaptable to construction in the wet because their location with respect to the river and the overburden conditions are such that construction in the dry will be economically impracticable; these walls consist of a series of steel sheet pile cells filled with granular material and support a continuous concrete wall spanning the cells. The lock gate and emergency dam sills are founded on rock, and were designed as concrete arches, thrusting against the lock chamber walls. Arch design for the upper sills was selected for reasons of economy, due to the considerable height of the sills above ledge rock; gravity sections could have been used for the lower sills, which have relatively low heights, but the arch shape was retained to duplicate the form panels required for the upper sills. Lock gates and protecting fenders, the emergency or lock-unwatering dams, filling and emptying features, and the approach guide walls are similar to those of the Robinson Bay Lock (see paragraph 52e). A bobtail, through truss, swing bridge is provided across the upper end of the lock for the relocated railroad and highway connections to Canada (see Feature No.35). It was designed for Coopers E-60 railroad loading and H-20 highway loading, both with impact. The miter gates, emergency dams, filling and emptying valves, wire rope fenders, swing bridge and other operating equipment, and all fixed metal parts and other details, where practicable, are duplicates of the corresponding items for Robinson Bay Lock. The pool regulation system was designed to discharge the estimated maximum probable flood runoff from the drain-

age area tributary to the intermediate pool between Grass River and Robinson Bay Locks with less than one foot rise in the normal pool level. Dike No. 7 on the south and No. 8 on the north side of the lock are required to complete the barrier system for maintenance of the navigation pool between the locks. They were designed in accordance with the criteria established for other dikes in the Long Sault Canal System (see paragraph 22). The lower approach channel is flared outward between the ends of the approach walls and the river to facilitate navigation of vessels in the cross currents which may exist near the mouth of Grass River.

f. Present Status of Plans and Specifications.- Plans, Specifications and Analysis of Design for Grass River Lock, with appurtenant works, are contained in Appendix III-20(1), (2), and (3). The status of the plans are the same as for Robinson Bay Lock (see paragraph 52f). It is considered that the drawings and specifications are sufficiently complete for the purpose of taking bids on the work. The analysis of design is in the form of a supplement to the Analysis for Robinson Bay Lock, which describes in detail the basis of design for most of the principal features which are common to both locks; the Analysis for Grass River Lock is limited to applicable items, which are materially different from those of Robinson Bay Lock.

g. Estimated Cost and Time Required to Complete Plans.- Prior to commencement of construction, it would be desirable to supplement the present data by additional subsurface exploration and soils tests. Probings and drill holes are needed along the alignment of the dikes to determine the profiles and character of the clay and till strata for use in checking the stability of the proposed dikes. A few additional holes are needed in the lock area for the purpose of obtaining undisturbed samples of clay for shear testing, to determine whether steeper excavation side slopes would be feasible. A minimum of two of these holes should be drilled 100 feet or more into the rock to determine whether cavities, gypsum beds, fault zones or other undesirable conditions exist in the deep strata. Explorations by a number of test pits and a few drill holes should be made in the prospective borrow areas for dike and embankment materials. At least two hydrostatic gages should be installed in the lock area to determine whether excess pore water pressure exists in the underlying marine clay. A hydraulic model study should be made to determine the location and extent of dredging, rock fill dikes, and other works necessary to improve current conditions at the mouth of Grass River and the entrance to the lower approach to the lock. It is contemplated to include this study with a general hydraulic model study of the entire river, from a point below Long Sault Dam to the head of Lake St. Francis, for the purpose of investigation of stages, velocities, and distribution of discharge produced by contemplated excavation in the north and south channels of the river and below the powerhouse. The minimum amount of the required additional subsurface exploration and soils testing is estimated to cost about $9,500 and could be performed in about three months. If undertaken prior to advertisement for bids, the investigations need not delay the construction schedule. The hydraulic model study recommended for Robinson Bay Lock to check the filling and emptying characteristics

would be applicable also to Grass River Lock (see paragraph 52g). Half of the estimated $6,000 of that study should properly be chargeable to Grass River Lock. This study could be made in two to three months during the early stages of construction, without causing delay in the work schedule. The cost of the general model study is estimated at $17,000, only a small percentage of which would be properly chargeable to Grass River Lock approach. The complete study might require seven or eight months, but the lock construction can proceed since it will not depend on the results of the tests.

h. Estimated Cost.- A summary of the estimated cost is given below. A detailed estimate is contained in Appendix III-20(3).

Contract Cost	$6,956,923
Materials and Equipment furnished by Government	2,055,225
	$9,012,148
Engineering and Contingencies (about 18%)	1,637,852
Total Cost	$10,650,000

55. FEATURE NO. 21 - SEAWAY VILLAGE, INCLUDING ACCESS ROUTES ON THE UNITED STATES SIDE.-

SEAWAY VILLAGE

a. Description and Purpose.- This work involves the construction of Seaway Village including an access highway and railroad to the village, Robinson Bay Lock and Long Sault Dam. The necessity for Seaway Village is set forth in Chapter II and as explained, its construction will be of temporary or semi-permanent type for quartering Government employees for five or six years. The site selected is on the Massena-Massena Center highway about three miles east of the village of Massena. This road, widened and improved, will constitute the main street of the village. The center line of this improved highway is marked by three bolts driven in the ground at points having the following coordinates on the Transverse Mercator system:

N - 1,805,453.57	N - 1,806,397.09	N - 1,805,635.25
E - 364,866.89	E - 367,202.56	E - 370,267.93

Approximately three hundred acres are included in the site, of which two hundred will be improved initially and the remainder as needed. The village includes an administration building and laboratory for the Engineer District; a guest house; residences, dormitories, etc., for housing the Government employees; a business section; recreational facilities; paved streets with sidewalks; and all necessary utilities and auxiliary facilities to constitute a self-contained village. The initial development will contain 570 residences, 30 of which will be of the two-family type, thus providing for a total of 600 families. The facilities will be expanded, if necessary, to 900 dwellings with additional dormitories, stores, and garages. Should extensive hired labor operations be under-

taken, provision has been made for a large number of second-class dormitories located immediately west of the village and served by its utilities. It is proposed to provide the following utilities and services: a spur track from the proposed yards of the Massena Terminal Railroad, electric power and light including street lighting, a central heating plant, a potable water supply, telephone service, a fire protection system, sanitary and storm water sewerage systems and disposal plant, parking areas, garbage and waste collection, snow removal and street cleaning service, and general repair shops for Government-owned utilities, buildings and equipment. The construction and installation of utilities, with the exception of the electric power and light system, will be accomplished under a general contract. Because a considerable quantity of the parts and materials required for the power and light system was available at Fort Peck, Montana, it was proposed to install the system by hired labor. The postponement of construction of the project will probably change this situation and make it desirable to include this work also in the general contract. Plans, specifications and analysis of design are contained in Appendix III-21(1), (2), and (3). Details pertaining to the operation of the various utilities and services are in Appendix III-21(3). For reasons set forth in paragraph 34a, P-0 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- No specific method was proposed in the Original 238-242 Plan for housing Government employees. It was intended that the unit prices and allowances for contingencies used in developing the original cost estimates would cover the cost of all such items.

c. Discussion.- An alternative to the construction of Seaway Village is the use of existing housing and office facilities which might be found available in Ogdensburg, New York, located approximately 40 miles west of Massena. Existing vacant mill property might be converted into office space. However, there is no assurance that sufficient suitable living quarters could be found. In view of the distance from the principal work area and the severe winter climate, this plan is not considered desirable. The location is 40 to 50 miles from the principal work area. The winters are so severe that travel is often hazardous and at times impossible.

d. Present Status of Plans.- Contract plans and specifications are completed except for the detailed structural drawings of the hospital which is approximately 50 per cent completed. The layout plans show the location of an incinerator, but no designs have been prepared. A base line for a survey of Seaway Village has been monumented, profiles of streets have been run; the bearing and distance to every street intersection have been computed and are shown on the drawings. Soil conditions have been investigated and bearing values established for all building foundations; lot lines and the type of house to be built on each lot have been determined. The location of all utilities is shown. The grades of the sewers and of the heating and water systems have been determined. All the foregoing and additional information are contained in the contract drawings, specifications and analysis of design in Appendices III-21(1), (2), and (3). Prior to construction, the layout as indicated on drawings

must be staked in the field, and additional profiles and sections taken, to determine quantities.

e. Estimated Cost and Time Required to Complete Plans for Seaway Village.- It is estimated that 207 man days will be required to complete the contract drawings, and the cost, including overhead, is estimated at $3,000. If time does not permit the completion of these drawings prior to the award of a contract, it is considered that the present state of completion is adequate to permit an award to be made with provision for some modification when plans are completed.

RAILROAD TO SEAWAY VILLAGE, ROBINSON BAY LOCK, AND LONG SAULT DAM FROM THE UNITED STATES SIDE

f. Alternate Plans.- Various plans for railroads to serve the downstream division (below Morrisburg) of the construction work were considered. Originally, a Government terminal yard was proposed east of Denison Road and south of Robinson Creek, shown as Seaway Terminal on Drawing No. MRR-R-1/1 and 2, Appendix III-21(1). This terminal yard was considered necessary because of the inadequate facilities owned by the Massena Terminal Railroad. The Railroad has since indicated willingness to construct a yard at Massena Springs, extend the tracks across the power canal and to construct a secondary yard immediately north of the Aluminum Plant, as indicated on Drawing MBRR-1-1/1. In this event, a Government yard will not be required. Plans for such construction have therefore been suspended for the present, but the results of the studies are given below in order to preserve them for future reference, should the need arise. Various methods of approach to the terminal yard were considered, the most feasible being the following:

(1) Connection with Massena Terminal Railroad.- A spur line about 12,000 feet in length estimated to cost $193,000 starts at the Massena Terminal Railroad and extends along the westerly bank of the power canal, crossing the canal on a temporary bridge and thence extending easterly to the terminal yard. This spur is indicated as Line A on Drawing No. MRR-R-1/1, Appendix III-21(1). The line could be readily constructed and spurs to the new aluminum plants and to Seaway Village would be practical. However, because of grades and alignment and the weakened conditions of the bridges on the existing Massena Terminal Railroad, it is doubtful whether a large volume of heavy traffic could be handled over this route. Two alternate routes are shown on the drawing, Lines C and B. Line C is about 16,900 feet long and is estimated to cost $330,000. A bridge across Grass River will be required. Line B was considered, but found more costly than other routes.

(2) Connection with New York Central Railroad.- A spur line from the New York Central Railroad tracks at Massena Springs was also considered. It is more costly as it is longer and involves bridges over both the Raquette and Grass Rivers. Its cost is estimated at $800,000, assuming that the bridges are used entirely for railroad purposes. If satisfactory arrangements cannot be made with the Massena Terminal Railroad, consideration should be given to this plan. It has the advantage of effecting a saving in freight charges as it would elimi-

nate the Massena Terminal Railroad, and permit the New York Central and Grand Trunk to deliver freight directly to the terminal yard. The Massena Terminal Railroad now charges the other railroads $5.50 per car for hauling from Massena Springs to Massena. Temporary and permanent tracks are proposed from the terminal yard to Long Sault Dam. The temporary tracks will cross Long Sault Canal on a plug left in the canal west of Robinson Bay Lock. The permanent tracks will cross the west end of the lock on a combined highway and railroad swing bridge and cross the ravine northwest of the lock on Dike No. 4.

(3) Connection with the Ottawa Branch of the New York Central Railroad.- Connection with the principal work areas from the Ottawa Branch of the New York Central Railroad is also possible. The proposed project provides for the relocation of this railroad as discussed under Feature No. 35. After relocation of the line across Grass River Lock, a spur could be provided to Hawkins Point, from which point the powerhouse site could be served by a ferry or overhead tramway, and thence extended to Robinson Bay Lock and Long Sault Dam. The cost of a permanent line from a point north of Grass River Lock to Long Sault Dam by way of Hawkins Point, Robinson Bay Lock site, and Dike No. 4 is estimated at $233,000. The estimated cost to provide temporary service before Dike No. 4 is constructed is $287,000, or a total of $520,000 for both permanent and temporary service. The temporary route will require a plug in the Long Sault Canal, east of Robinson Creek. The cost of a permanent line from a point south of Grass River Lock through the area north of the North Grass River Road and by way of Robinson Bay Lock and Dike No. 4 to Long Sault Dam is estimated at $773,000. To provide temporary service before the lock and dike are completed would cost an additional $182,000, or an estimated total of $955,000, for both permanent and temporary service. A summary of the estimated cost for the alternate methods of providing temporary and permanent rail connection to Seaway Village, Robinson Bay Lock, and Long Sault Dam follows:

Connection from Massena Terminal Railroad via proposed Government terminal yard (Line A, Drawing MRR-R-1/1)..	$193,000
Connection from the New York Central Railroad (Massena Springs Terminal) via proposed Government terminal yard..	$800,000
Connection from the relocated Ottawa Branch, New York Central Railroad at Grass River Lock..................	$520,000

The plan indicated as Line A has the lowest first cost and is recommended for adoption if satisfactory arrangements can be made with the Massena Terminal Railroad. It is understood that the Aluminum Company favors this line. During the latter stages of preparation of this report, the Massena Terminal Railroad Company officials stated that they would extend their tracks and construct the proposed yard north of the Aluminum Plant if the proposed St. Lawrence River project were constructed. The work schedules, contracts and cost estimates in this report were based on this assumption. Attention is invited to Drawings Nos. MBRR-1-1/1-12, Appendix III-21(1). Drawing No. MBRR-1-1/1 shows the general plan of the railroad layout on which the estimates of cost are based and the portion assigned to each contract. This plan provides for temporary and perma-

nent tracks to Seaway Village, Robinson Bay Lock, Long Salt Dam and Barnhart Island powerhouse. Drawing No. MBRR-1-2/1 shows the plan of subsurface explorations between Grass River and Long Sault Dam. These rail connections are required at the beginning of operations and have been assigned P-0 priority.

HIGHWAY TO SEAWAY VILLAGE, ROBINSON BAY LOCK LONG SAULT DAM, AND BARNHART ISLAND POWERHOUSE FROM THE UNITED STATES SIDE

g. Proposed Plan.- Highway connection from the United States side to the downstream division (below Morrisburg) of the proposed project will be obtained by improving existing roads and by the construction of a permanent road from State Highway No. 37 on the south bank of Grass River to the Barnhart Island Powerhouse by way of Robinson Bay Lock, Dike No. 4, and Long Sault Dam. Pending the construction of the lock and dike, temporary facilities will be provided over a temporary plug in the canal west of the lock. The new road will cross Grass River on a temporary bridge to be constructed at a site east of the existing cantilever bridge leading from Route 37 to the Aluminum Plant. Recent information indicates that the existing cantilever bridge will be strengthened to a capacity of 20 tons. In this event, construction of the temporary bridge should be postponed until the need for it is demonstrated, and the new road construction should start with the improvement of the North Grass River Road beginning at or near the northerly end of the existing cantilever bridge. Present plans also provide for the improvement of the North Grass River Road throughout its length and its extension to the Grass River Lock site, and also the improvement of Horton Road leading through the site of Seaway Village from North Grass River Road to Middle Road. Drawings MBHN-1-1/1-14 and MBHN-1-90/1-8, Appendix III-21(1), Part II, show the plan, profile, bridge plan and bridge details of the connecting highway to the powerhouse, and Drawings ML-2-185/1-6 show the plan and profile of the road leading from Massena Center to Grass River Lock. The extent and location of the explorations conducted at various bridge sites are shown on Drawing MRR-A-2/1. The construction of these roads and railroad is included in various contracts as indicated on the drawings. For reasons set forth in paragraph 34a, these highway connections have been assigned P-0 priority.

h. Treatment under the Original 238-242 Plan.- Connecting railroad and highway routes are not indicated on the Original 238-242 Plan. The costs of such features were included in unit prices and in allowances for contingencies.

i. Present Status of Plans.- Preliminary studies only have been made. Plans and profiles were developed from the Ross Survey Maps. Additional profiles and cross sections will be required for the determination of final alignment and grade, and for estimate of quantities. Soil investigation will be necessary in some areas to determine foundation conditions.

j. Estimated Cost and Time Required to Complete Plans.- It is estimated that three months will be required to complete the field work and engineering for the connecting highway at a cost of $7,500. Delay

in this work might delay construction of the larger features of the project.

k. Alternate Plan.- A temporary, timber, deck truss, highway bridge across Grass River, 22 feet wide, was planned as part of the connecting highway from Route 37 to Seaway Village, Long Sault Dam, Grass River Lock, Robinson Bay Lock, Long Sault Canal and the Barnhart Island powerhouse, in the event that the existing cantilever bridge which crosses the Grass River at the Aluminum Plant is not strengthened or is found to be inadequate. A short movable span comprising the central portion of the proposed bridge which could be moved out of position on a barge or lifted by derricks will provide sufficient clearance for a dredge, at times used by the Aluminum Company. The existing cantilever bridge, located about 1,000 feet west of the proposed new bridge, is designed for a maximum load of only 10 tons, and has an 18-foot roadway. It would, therefore, be inadequate for the heavy traffic which will exist during construction.

l. Discussion.- The highway traffic through the center of Massena and across the Grass River by way of the Main Street Bridge is at present of such volume that additional traffic would cause very costly delays in getting men and materials to the work sites. The proposed bridge will bypass the business center of Massena. Subsurface exploration was conducted at three sites during the studies. One site was located across the Massena Power Canal and two sites were located across the Grass River. One of the latter sites located about 1,000 feet downstream from the existing cantilever bridge was selected for the final location. The explorations consisted of drilling in overburden and rock, probing, and the determination of the elevation of bedrock by the seismic method. The locations and records of the explorations are shown on Drawing MRR-A-2/1, Appendix III-21(1), Part II. The bridge is designed for the Standard H-20 loading. Ice conditions in the river necessitated a minimum number of piers. Since the bridge will be of a temporary nature, untreated timber deck trusses are proposed.

m. Present Status of Plans.- Plans for both superstructure and substructure have been completed. Specifications and analysis of design have not been prepared.

n. Estimated Cost and Time Required to Complete Plans.- The estimated cost for completing specifications and analysis of design for the Grass River Highway Bridge is $1,000. and the time required is approximately three weeks. Estimated time to construct the bridge is four months.

o. Estimated Cost.- A summary of the estimated cost of Seaway Village is shown below. There is also shown a summary of the estimated cost of power for construction, fully discussed in Chapter II, paragraph 27. Detailed estimates are contained in Appendix III-21(3) and Appendix A-2, respectively.

(1) Seaway Village.-

Contract Cost..........................	$4,788,258	
Engineering and Contingencies (about 18%)......................	861,742	
Total Cost of Seaway Village.......		$5,650,000

(2) Power for Construction.-

Contract Cost..........................	$ 184,000	
Engineering and Contingencies (about 18%)......................	33,000	
Total Cost of Power for Construction		217,000
Total Cost of Items (1) and (2)....		$5,867,000

The cost of the temporary, connecting highway from the cantilever bridge at the Aluminum Plant to Long Sault Dam, and the connecting railroads from the proposed yards of the Massena Terminal Railroad north of the Aluminum Plant to Long Sault Dam, a total of approximately $392,000 is included in the cost estimates for Long Sault Dam (Feature No.22). The cost of the additional work to provide permanent highways and railroads on the United States side is included in the estimates for Robinson Bay Lock (Feature No. 18); Long Sault Dam (Feature No. 22); and Barnhart Island Powerhouse (Feature No. 24). It is believed that the present cantilever highway bridge across Grass River at the Aluminum Plant will be strengthened by the County and that the proposed alternate temporary highway bridge across Grass River (see paragraph 55k) will not be required. Therefore, no estimate for the latter is included.

56. FEATURE NO. 22 - LONG SAULT DAM AND ATTACHED DIKES.- a. Description and Purpose.- The Long Sault Dam is a concrete gravity structure consisting of an overflow spillway flanked on either side by concrete gravity bulkheads or non-overflow sections, with short earth wing dams extending to high ground. It is curved in plan, with a radius of 1,600 feet. The main structure extends from the south mainland to the head of Barnhart Island, while the shore sections will complete the closure to high land on the island and the mainland. The purpose of the structure is to control the main (south) channel of the St. Lawrence River for creation of the power pool and to serve as the flood and emergency spillway for this pool. The Barnhart Island powerhouse with flanking earth dikes along Barnhart Island and across the channels between Barnhart Island and the Canadian mainland near the east end of the island, will constitute an extension of the dam. The Mercator Coordinates of the Long Sault Dam are shown on the contract plans. The south end of the spillway at the axis of the dam is at point N. 1,820,024.305, E. 362,609, and the north end of the spillway at the axis is at point N. 1,822,141.091, E. 363,327.375. For reasons set forth in paragraph 34b (9), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a similar dam for the same purpose located approximately 1,000 feet upstream from the site now proposed. The exact location and detailed plans are not available, but the map and estimate made

by the Canadian Department of Transport indicate that the same general scheme of diversions during construction, including the raising of Lock 21 was contemplated. In the original plan, the spillway was shown about 50 per cent longer and the gate sills two feet higher than now proposed, but the regulatory effects on the river are practically the same in both cases. The changed location and details of design were made as a result of additional subsurface exploratory data, and it is considered that they will effect a substantial saving in cost.

c. Additional Data Secured. - Additional foundation explorations were made which disclosed valuable information not heretofore available, particularly with respect to the elevation of sound rock near the lower end of Long Sault Island and in the deep channel between Long Sault and Barnhart Islands.

d. Discussion.- The seismic and drilling explorations disclosed that sound rock at the east end of Long Sault Island is at higher elevation than previously considered, and that the slope of the surface of the bedrock below this point is less precipitous than the slope of the channel. In view of this information, investigations into the feasibility of locating the dam downstream in order to reduce its length were undertaken. The studies considered all features, including cofferdam and diversion costs. The proposed location, about 1,000 feet downstream from the earlier one, was determined to be the most economical. Although the dam could be further shortened by locating it still further downstream, the bedrock is at lower elevations and the cost of the dam and the cofferdam would, therefore, be increased. It was found impractical to shorten the spillway further by additional lowering of its crest because of increased gate costs and decreased stability. In the plans for diversion of the river flow during construction advantage was taken of the division of the river into two channels by Long Sault Island immediately upstream from the dam site. It is proposed to divert the entire flow through either channel while the other is closed to permit construction of the corresponding section of the dam. This program will require the excavation of the three diversion cuts, which are among the major items in the contract. In order to maintain natural flow in the upper reaches of the south channel, to prevent interference with the supply to the Massena Power Canal, it will be necessary that the flow of the south channel be diverted into the north channel through a cut across the lower end of Long Sault Island (Cut C) during the first stage of construction. In order to construct the northern part of the dam in the dry (second stage of construction) the flow in the north channel will be diverted across Long Sault Island, to the lower portion of the south channel through Cut F. The limited capacity of the south channel will require the enlargement of the lower portion by the excavation of Cut G (see Plate M-1). The water level in the pool is the basic controlling factor for most of the project construction operations. These levels depend directly on the construction stages and closure operations for the Long Sault Dam which are in turn dependent upon and controlled by progress of construction of the Barnhart Island powerhouse. The latter, because of its magnitude, determines the progress of the construction program as a whole. It is believed that the length of the various stages of project construction, as determined by progress on the powerhouse, will

be sufficient to permit all other inter-related features of the project to be accomplished to best advantage under the work schedule previously discussed. A more detailed discussion of the diversion during construction, and of the factors which controlled the design of the diversion cuts, are contained in Section XIV of the Analysis of Design for the Long Sault Dam, Appendix III-22(3). Present navigation facilities through the Canadian locks, bypassing the Long Sault Rapids, permit creation of a pool only to elevation 205. In order to maintain the present facilities until the pool is raised to final level, it is proposed to raise the coping of Lock 21 to elevation 210, and reconstruct the dike between the canal and the river, and the dike on the north side of the lock, to the same elevation.

e. Recommended Plan.- The Long Sault Dam is a concrete gravity structure with maximum height of about 145 feet above foundation. It includes an overflow spillway, crest elevation 221.0 flanked by concrete gravity bulkhead sections, earth wing dams and earth dikes. The center line of the main structure is an arc of 1,600 feet radius. Forty spillway openings, with vertical lift, roller type, crest gates 25 feet in height, operated by two traveling gantry cranes, will bypass water not used in the powerhouse. The spillway apron and bucket will be constructed as an integral part of the structure as the depth of tailwater renders a long stilling basin unnecessary. The crest length of the spillway is 2,390 feet, of which 2,000 feet are clear spillway openings. The concrete bulkheads at each end of the spillway are approximately 260 feet long. The wing dams and dikes will be of compacted earth, protected on both sides with riprap. The Long Sault Dam and attached dikes, in conjunction with the Barnhart Island powerhouse and its attached dikes, will control all channels of the St. Lawrence River and will raise the water to the ultimate operating level, elevation 242, thereby developing all available head between the powerhouse and Chimney Point.

f. Present Status of Plans and Specifications.- The general plans, specifications, and design analysis for the Long Sault Dam have been completed and comprise Appendices III-22(1), (2) and (3). The plans and specifications are sufficiently complete to permit advertising for bids for the construction of the dam and its flanking earth dikes. The plans provide for the erection of the gates, individual hoists, two traveling gantry cranes, and the electrical conduits. Plans and specifications for the purchase of the gates and the one gantry crane required for diversion, and sufficient reinforcing steel to complete the south bulkhead and the spillway from Piers 1 to 14, inclusive, together with the bridge plate girders, complete for the entire dam, have been prepared and are included in Appendices III-22(1) and III-22(2), Part Two. It was intended to include only the portions of equipment that will be initially required in order to keep the immediate requirements for steel and machinery to a minimum. Specifications for the second gantry crane, for the remainder of the spillway gates, with their individual hoists, and for the balance of the reinforcing and structural steel, can be readily prepared by altering a few features of Appendix III-22(2), Part Two. Only the technical requirements have been covered in this Appendix as the general requirements ordinarily included in Section I of specifications, are subject to frequent changes.

g. Estimated Cost and Time Required to Complete Plans.- During construction of the Long Sault Dam from the south shore up to and including Pier No. 14, which constitutes the first stage of construction, ample time will be available for the preparation of plans and specifications, and for fabrication and delivery of the spillway gates, hoists, crane, structural and reinforcing steel, etc., required for the remainder of the structure. It will be necessary to make a hydraulic model test in order to determine the shape of the stilling bucket for the spillway. This test could be completed in about three months and it should be initiated shortly after the first contract is awarded. It is estimated that the cost of the additional preliminary work will be approximately $100,000, including the cost of the hydraulic model study. It is believed that this work can be planned so as not to conflict with the work schedule for the Long Sault Dam or increase the time required for its construction.

h. Estimated Cost.- A summary of the estimated cost for the Long Sault Dam is shown below. A detailed statement of estimates of the cost of the general construction contract and of the materials and equipment to be furnished by the Government are contained in Appendix III-22(3).

(1) Long Sault Dam

Contract Cost........................	$8,857,975	
Materials and Equipment furnished by Government....................	7,712,485	
	$16,570,460	
Engineering and Contingencies (about 18%)......................	2,982,540	
Total Cost..................		$19,553,000

(2) Raising Lock No. 21

Contract Cost........................	$ 100,000	
Engineering and Contingencies (about 25%)......................	25,000	
Total Cost..................		125,000
Grand Total..................		$19,678,000

57. FEATURE NO. 23 - BARNHART ISLAND SOUTH FOREBAY DIKE.- a. Description and Purpose.- The Barnhart Island South Forebay Dike will be an earth wing dam extending westerly from the westerly end of the United States portion of the powerhouse to high ground near the center of Barnhart Island. It will be a compacted earth dike protected by riprap on the upstream face and with adequate downstream drainage. The final details of design have not been prepared; however, it is known that at least part of the foundation is pervious gravel and therefore special designs and additional subsurface investigations will be required. For general location and other information see Drawings BP-1-1/1 and BP-1-20/1, Appendix III-24(1). For reasons set forth in paragraph 34b(10), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Barnhart Island South Forebay Dike was shown in the Original 238-242 Plan as a standard section earth dike in approximately the same location as now planned and intended to serve the same purpose. No specific data regarding foundation conditions were available when the original plan was made and some changes in details of design will probably be required as a result of more complete subsurface information.

c. Additional Data Secured.- A number of borings at the site of the Barnhart Island South Forebay Dike indicate a thick bed of pervious gravel under the proposed dike. Analysis of conditions at the site of this dike is given under "Analysis of Design, Barnhart Island Powerhouse Dikes and Cofferdams" in Appendix III-24(3).

d. Discussion.- The additional subsurface explorations will provide more definite information regarding the pervious gravel formations under at least part of the proposed dike. An alternate location for a portion of the dike near the powerhouse was considered as indicated on Drawing BP-1-1/1, Appendix III-24(1). The method proposed for carrying power from the powerhouse to the Barnhart Island Switchyard is a governing factor in the choice of locations for the dike. If this is done by cables placed in tunnels, the short, direct route for the dike could be used, whereas if overhead conductors carried on towers are used, the indirect route would be desirable. See also Drawings BP-A-2/1 and BP-A-2/6 in Parts II and III, respectively, of Appendix III-24(3).

e. Present Status of Plans.- Final plans for this dike have not been prepared. Additional borings and soils studies at the site should be made before completion of the final design. It is estimated that the total cost of all preliminary work which will be required before contracts can be awarded for the Barnhart Island South Forebay Dike will be $25,000 and the work can be completed within three months.

f. Estimated Cost.- The estimated cost is given below. It is included in the estimate of cost of the Barnhart Island Powerhouse (Feature No. 24).

Contract cost.........................	$1,020,000
Engineering and Contingencies (about 18%	180,000
Total Cost.....$1,200,000	

58. FEATURE NO. 24 - BARNHART ISLAND POWERHOUSE.- a. Description and Purpose.- The Barnhart Island Powerhouse with attached dikes, in conjunction with Long Sault Dam and its attached dikes, controls all channels of the St. Lawrence River in the vicinity of Barnhart Island, creates the pool for the development of power and the improvement of navigation in the International Rapids Section, and houses the necessary generating equipment. The powerhouse is 3,585 feet long, half being located on each side of the international boundary line. The total proposed installed capacity is 2,200,000 horsepower. The general plans and details of the feature are shown on the contract drawings in Appendix III-24(1).

For reasons set forth in paragraph 34b(12) and discussed below, P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a powerhouse of the same installed capacity, intended to serve the same purpose but located approximately 800 feet upstream from the site now proposed.

c. Additional Data Secured.- Considerable additional subsurface exploration work in the vicinity of the powerhouse was performed and additional hydrographic and topographic surveys were made.

d. Discussion.- (1) The Barnhart Island Powerhouse is the largest single feature of the project, and its construction will require the greatest expenditure of materials, time, labor, and money. It serves the purpose of a dam across the channels north of Barnhart Island required for creation of the pool. It will be necessary to defer the closure of the Long Sault Dam and creation of the pool until the substructure of the powerhouse is substantially completed and the head gates or equivalent stop-logs are installed. Creation of the pool is a controlling factor in the work schedule for many features of the project, including dikes and channel work. Consequently, the rate of construction of the powerhouse will govern the construction program for the entire project and every effort must be made to provide for the prompt initiation and vigorous prosecution of this feature.

(2) The profile of the International Rapids Section of the St. Lawrence River discloses that any plan for a major power development in this reach will involve a dam and powerhouse near the foot of the Long Sault Rapids, while a glance at the map shows that one of these will probably lie between Barnhart Island and the Canadian shore and the other between the island and the United States shore. In earlier studies, several locations within these limits were considered, including one south of Massena Point near the mouth of the Grass River. The International Agreement of March 19, 1941, definitely fixed the location of the dam at the head of Barnhart Island and the powerhouse between the foot of the island and the Canadian shore.

(3) After review of the hydrological studies previously made by the Canadian Department of Transport, it was decided to make no further hydrologic studies for this feature, and to adopt the data and plan of flow regulation set forth in its Regulation Plan No. 5 (see "Lake Ontario - Levels, Outflows, Supplies and Regulation", a copy of which is included in Appendix A-2) as the basis of powerhouse design. Necessary hydrographic and topographic surveys and subsurface exploration were undertaken by district forces and a contract was entered into with the Harza Engineering Company of Chicago, Illinois, to make engineering studies and prepare plans and specifications for the construction of the powerhouse and for the purchase of the turbines, governors, and generators for the U. S. half of the installation. Consulting engineers were engaged to advise on all important problems. As work under the Harza contract progressed, joint meetings of the United States and Canadian Advisory Committees were held at which all major questions pertaining to the layout

and design of the powerhouse and equipment were discussed. Since it was contemplated that the powerhouse would be operated by the New York State Power Authority and the Hydro-Electric Power Commission of Ontario, particular weight was given to the desires of the representatives of these organizations in all matters affecting operation, and the District Engineer and the Harza Engineering Company held informal consultations with their representatives to consider details of powerhouse design. However, the full membership of the Advisory Committees was kept informed of the progress of the work and concurred in all major engineering decisions.

(4) It was understood that the project as set forth in the International Agreement included the powerhouse and electrical and mechanical equipment for the generation of power, but did not include step-up transformers, high tension cables or conductors for transmission of the power from the powerhouse or switchyards, and equipment for connection to transmission lines. All necessary equipment of this kind must be provided by the operating agencies. However, space for their installation must be provided in the powerhouse and the surrounding area, and the type and layout of such equipment will govern many items of design of the powerhouse structure. Accordingly, the contract with the Harza Engineering Company provided for study of this matter to the extent of determining the layout and type of equipment. These determinations were concurred in by the Advisory Committees.

(5) The district forces conducted subsurface investigations at the powerhouse site to determine the characteristics of the overburden and bedrock. A description of the laboratory tests, the location of drill holes, etc., and methods used in all field explorations is contained in Part II of Appendix III-24(3). All these data were made available to the Harza Engineering Company. Additional explorations will be required during or prior to construction to determine the size and location of various gypsum beds which were not fully developed. The explorations will be performed in connection with the exploratory holes for grouting the foundation. Additional exploration will also be required prior to or during construction at the sites of cofferdams A and B and on the forebay dikes, to check the design of the sections shown on the contract drawings.

(6) The contract with the Harza Engineering Company provided for submission of a preliminary report to include the following:

Study to determine most advantageous location of powerhouse and sluiceways; most economical and practical type, rating and spacing of generating units; and most economical design and location of interior electrical equipment and out-of-door high tension substations.

Estimate of cost of recommended power plant and appurtenant works.

Description of recommended features, giving type, rating and characteristics of major items of equipment.

Sketch plans to accompany the report including, but not restricted to the following:

General location plan.
Elevations of power plant.
Turbine floor plan.
Generator floor plan.
Control room floor plan.
Cross section through unit.
Longitudinal section through powerhouse.
Sections of ice and trash sluices.
Sections of wing walls.
Layout of high tension substations.

This report was submitted on June 21, 1941, and is included in Appendix III-24(3). After study of this preliminary report by the Advisory Committees, the District Engineer, the Office of the Chief of Engineers, and certain of the consultants, the Harza Engineering Company was instructed to proceed with the preparation of plans and specifications. These instructions included the decisions of the Advisory Boards upon various questions which had not been definitely determined in the preliminary report. The most important of these decisions were

The selection of the location designated "C" in the preliminary report.

The arrangement of generating units and step-up transformers in the following order from south to north.

12 U. S. units for 60 cycles, 230 kv.
6 U. S. units for 60 cycles, 115 kv.
6 Canadian units for 60 cycles, 115 kv.
12 Canadian units for 25 cycles, 230 kv.

Transmission of power from the powerhouse to the switchyards as set forth in paragraph 58e(8).

Location of transformers on the downstream side of the powerhouse; provisions to be made for one bank of single phase transformers for each pair of generators except a separate bank of half the capacity for each of certain 60-cycle units as may be desired by the Canadian authorities.

No large sluiceway to be provided between the powerhouses; pool to be regulated by the crest gates of the Long Sault Dam, some of which will be equipped with individual gate hoists for this purpose.

Six ice sluices to be provided, with crests at elevation 229.0; two 75-foot ice sluices at each end of the powerhouse and two 50-foot in the center.

The design of scroll cases and draft tubes to be such that there will be a solid buttress of concrete between each pair of adjacent units extending through the substructure from forebay to tailrace in a straight line at right angles to the

center line of the powerhouse.

(7) On the foregoing basis the Harza Engineering Company proceeded with the preparation of contract plans and specifications for the main contract for the construction of the powerhouse, and for the purchase of the turbines, governors and generators for the United States half. During the course of this work, the company kept close contact with the District Engineer, the Office, Chief of Engineers, and the members of the Advisory Committees. Frequent consultations were held and partially completed work was submitted for approval. After the Harza Engineering Company completed the plans and specifications, they were reviewed by the District Engineer and the Office, Chief of Engineers, and many revisions and additions were made. These, however, pertained only to details of design and arrangement. All the essential points of the completed plans and specifications have met with the approval of the Advisory Boards, either formally or informally. The plans, specifications, and analysis of design are contained in Appendices III-24(1), (2) and (3).

e. Recommended Plan.- (1) The powerhouse as now proposed is a structure 3,585 feet long and 180 feet wide, divided at the center by the international boundary line. Starting from the boundary line and proceeding shoreward, each half consists of one ice sluice at midstream, one house unit, 18 main units, and two ice sluices at the abutment end. For general plan and sections of powerhouse, see contract drawings in Appendix III-24(1).

(2) The intakes to the turbines consist of three passages for each, and will be equipped with trash racks, stop-logs, and head gates. The trash racks will be placed in sloping slots at the upper end of the intake passages and will be designed for easy cleaning, quick and simple removal or replacement by means of an upstream gantry crane. Adjacent to the trash racks will be located the slots for the stop-logs. Immediately downstream from the stop-logs will be the intake service gates. They will be wheeled gates, of structural steel in three sections, to be bolted together at the site. The scroll cases for the 18 main turbines will be unlined reinforced concrete. The scroll case for the house turbine will be steel plate.

(3) The turbines for the 18 main units are of the vertical shaft Francis type, having a capacity at best gate of not less than 61,100 horsepower at an effective head of 81 feet, and a capacity of 67,100 horsepower at full gate. At heads greater than 85 feet, the turbine gate opening will be limited so that the maximum output will not exceed 72,200 horsepower. The turbine for the house unit will have a capacity at full gate of not less than 9,000 horsepower at an effective head of 81 feet. At heads greater than 81 feet, the turbine gate opening will be limited so that the maximum output will not exceed this rated capacity. The rated speeds will be 69.2 revolutions per minute for the 67,100 horsepower turbines and 150 revolutions per minute for the 9,000 horsepower turbine. The draft tubes will be of the simple elbow type, provided with stop-log slots for unwatering. These stop-logs will be handled by an overhead traveling crane located in a gallery above the tailrace.

(4) In each of the two powerhouses, there will be eighteen generators rated at 55,000 kva, 3-phase, 13,800 volt, 69.2 revolutions per minute, 95 per cent power factor. Each unit will be equipped with a direct connected main exciter and pilot exciter, thrust and guide bearings, air coolers, voltage regulators, rheostats and field breaker panel. Twelve of the main generators in the Canadian powerhouse will be 25-cycle and will operate at a slightly different speed. These will be located at the center end. All of the units in the American powerhouse will be 60-cycle. The house service unit in each powerhouse will be a generator rated at 7,500 kva, 60-cycle, 3-phase, 13,800 volt 150 revolutions per minute, 85 per cent power factor. It will be of vertical shaft, umbrella or overhung type equipped with direct connected exciter, thrust and guide bearings, air coolers, field rheostat and field breaker panel.

(5) The main generator room of the powerhouses will each be equipped with two 300-ton cranes of the overhead traveling bridge type with double trolley hoists having a main and auxiliary hook each.

(6) The main step-up transformers will be located on the downstream side of the powerhouses at the generator floor level. They will be arranged in banks of three transformers for each two main units. Space will be provided in the Canadian powerhouse for the provision of an individual bank of smaller transformers for each 60-cycle generator, if desired. A service and transformer track will extend the full length of the powerhouse along the downstream side of the transformers. This service track will have a connection to the railroad systems on the Canadian shore, and will be linked to the railroad systems on the American shore by a connection on Barnhart Island and across Long Sault Dam.

(7) The extra space provided in the ice chute bays and in the end bays of the powerhouse is ample to permit the disassembly of two complete units in each powerhouse. Space is also available in these areas for machine shop, erection, welding and grinding of runners, storage of spare runners and for maintenance work on the transformers. Space for offices, control room, and other facilities is available in the end bays. Visitors galleries and elevators are provided throughout the powerhouses.

(8) The method of conducting high tension power from the transformers at the powerhouse to switchyards on shore was not definitely determined. In each powerhouse, power from the six units farthest from the shore will be conducted at 115,000 volts by high tension cables carried in galleries or ducts. The use of cables to conduct the high tension power from the remaining twelve units in each powerhouse at 230,000 volts involves certain technical difficulties, and some electrical engineers expressed a preference for the use of overhead conductors. The Advisory Committees finally decided that the plans and specifications should be based on the use of 230,000 volt cable, but that provision should be made for possible change to overhead conductors for either or both of the two groups of 12 units. The use of overhead conductors would require high structural steel towers connected by latticed girders and supported by the tower legs resting on the walls between the transformer

bays, on the upstream side, and on the top of the draft tube piers, on the downstream side. From this structure, the conductors on the Canadian side would have a maximum span of 1,700 feet to the shore towers located on the north forebay dike, thence average spans of 1,300 feet to the switchyard crossing the lower approach to the new Cornwall Canal Lock. The tower structure on the United States side would be located behind the south forebay dike, giving a maximum span of 1,800 feet. However, if underground cables are used to conduct the power to the switchyards, the south forebay dike on Barnhart Island should be relocated to the dotted position shown on the plan in Drawing BP-1-1/1. The location of the north forebay dike on the Canadian side will not be affected by the method used for conducting the power to the switchyard. A detailed discussion of the underground cables and the overhead conductors is contained in the preliminary report of the Harza Engineering Company (Appendix III-24(3), Part I B) in paragraph 8, under "Physical Arrangement of Electrical Equipment". It is recommended that the underground cable system for conducting the power to the switchyard be used as shown in the Harza preliminary report, Drawing SLP-N-9 "Location C Electrical Arrangement Scheme 2".

f. Present Status of Plans and Specifications.- The plans and specifications in Appendices III-24(1) and (2) include only the main contract for the construction of the powerhouse, and purchase and installation of the turbines, governors and generators. It is provided that the United States will furnish cement and aggregate for the concrete; specifications for the purchase of concrete aggregate are contained in Appendix C. Numerous other contracts will be required for the completion of the powerhouse. Such items as ice sluice gates, head gates, gantry and traveling cranes were designed only to the extent necessary to provide for their installation. A separate contract or contracts will be required for the architectural finish of the powerhouse including interior partitions, doors, tile flooring, interior finish of walls and ceilings, plumbing, lighting, ventilation, etc. Other contracts will cover the furnishing and installation of switch gear, control boards, relays, air compressors, machine shop equipment, oil purification equipment, etc. Since one to three years will elapse from the time work is commenced on the main construction contract until the foregoing items are required, it has not been necessary to design them in detail at this time. Furthermore, sufficient funds for this work were not available. When the construction of the project is authorized, funds should be made available and work started at once on completing the design of these items. The design of the scroll cases of the main turbines, shown in plans in Appendix III-24(1), was made by the Harza Engineering Company after consultation with the District Engineer, Advisory Committees, and turbine manufacturers. It represents, to some extent, a compromise between somewhat divergent views. After the plans and specifications were substantially completed, a committee of turbine manufacturers made objections to this design and submitted an alternate plan. Time did not permit a complete study of this matter and the plans have not been changed. If the manufacturers' scroll case design were adopted, the elevation of the generator floor would be materially increased. It is believed that the time which must elapse between the authorization of the project and the placing of concrete in the upper part of the power-

house substructure will be sufficient to permit model studies of the scroll case, including turbine and draft tube, and the termination of any changes in the design which may be required in order to produce the maximum hydraulic efficiency compatible with economic considerations. Model tests will also be required for the ice chute bucket and the downstream wing wall on the Canadian shore. The model test for the ice chute bucket will determine the best shape of this structure for the least turbulence and the effect of this turbulence on the concrete floor spanning the opening. The model test for the wing wall will furnish information needed for the design of the structure.

g. Estimated Cost.- The following summary of the estimated cost of the powerhouse amounting to a total of $148,044,000 includes both the American and Canadian powerhouses fully equipped, for the development of 2,200,000 horsepower, up to the low tension terminals of the step-up transformers. There are also included in this estimate $1,200,000 for South Forebay Dike (see Feature No.23); $568,000 for railways, highways, and bridges from the Canadian side (see Feature No. 29); and $2,412,000 for dredging Crab Island shoal and the tailrace (see Feature No. 32). The cost of each item includes engineering and contingencies. A detailed estimate of cost is contained in Appendix III-24(3), Part IV.

(1) Structures

Powerhouse Cost (excluding Feature No. 23 and items furnished by Government)	$32,963,000	
Cost of Feature No. 23 (South Forebay Dike)	1,200,000	$34,163,000
Materials and Equipment furnished by the Government	17,002,000*	
Additional Future Cost	2,502,000	19,504,000
Total Cost of Powerhouse Structure and Feature No. 23		53,667,000
Cost of Feature No. 29 (railroad and highway from Canadian side)	568,000	
Cost of Feature No. 32 (excavation of Crab Island and tailrace area outside of cofferdams)	2,412,000	2,980,000
Total Cost of Powerhouse and Feature Nos. 23, 29 and 32		$56,647,000

(continued)

(2) Machinery

Cost of Machinery and Equipment on United States Side	$47,491,000	
Cost of Machinery and Equipment on Canadian Side	43,906,000	
		$91,397,000
Total Cost of Feature No. 24 including Features Nos. 23, 29 and 32		$148,044,000

* The items furnished by the Government include the following:

1. Portland Cement and Aggregate.
2. Turbine embedded parts.
3. Service gate-sills, guides, stop logs, racks and hoists.
4. Ice gates and stop logs.
5. Cranes

59. FEATURE NO. 25 - MINOR DIKES, CANADIAN SIDE.- a. Description and Purpose.- Four minor dikes on the Canadian side designated as the Bergen Lake Dike No. 1, Moulinette Dikes Nos. 1 and 2, and the Mille Roches Dike are required at points north of Bergen Lake to retain the pool. These dikes were proposed under the Original 238-242 Plan, and as no new studies have been made, the locations were not changed. Exploration at the sites consisted of geological reconnaissance only. The proposed locations are shown on Plate M-1. Quantity and cost estimates were made for the dikes, assuming the sections to be similar to those shown on Drawing EP-1-20/1 in Appendix III-24(1) for the Barnhart Island powerhouse south forebay dike. Before the locations can be definitely established and the dikes designed, surveys must be made at each dike site and the exploration recommended under "Subsurface Investigations and Earthwork Design for the Cornwall Canal Relocation" in Appendix III-O(3) completed. The cost of the additional surveying, exploration and engineering is estimated at $2,500. These dikes do not require completion before the end of the second stage of construction, and have therefore been given P-2 priority. The lack of detailed plans for this feature will not interfere with the work schedule.

b. Estimated Cost.- The estimated cost of this feature is given below:

Designation	Quantity (Cu. Yds.)	Unit Price	Amount
Embankment	105,400	.62	$65,348
Riprap	29,000	1.50	43,500
Backing	14,400	1.75	25,200
Stripping	15,500	.35	5,425
Contract Cost			$139,473
Engineering and Contingencies (about 25%)			35,527
Total Cost			$175,000

60. FEATURE NO. 26 - NEW CORNWALL CANAL DIKE AND DRAINAGE DITCH.- a. Description and Purpose.- A dike, designated as the New Cornwall Canal Dike, is necessary to retain the pool between the proposed new Cornwall Canal Lock and a point approximately 1/2 mile north of Mille Roches. The proposed alignment is shown on Plate M-1. A drainage ditch to divert Robertson Creek to a point below the proposed new Cornwall Canal Lock is required because the New Cornwall Canal Dike will obstruct the natural drainage course. For reasons set forth in paragraph 34c(11), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a similar dike for the same purpose, but the location as now proposed has been changed to correspond to the new location of the powerhouse and to the change in plans regarding the location of the new Cornwall Canal as discussed under Feature No. 27.

c. Additional Data Secured.- Considerable drilling and probing was made along the alignment of the proposed New Cornwall Canal Dike, particularly in the vicinity of the proposed new lock, Robertson Creek, and in the valleys near the west end of the dike. The location, extent and records of all explorations are shown in Appendix III-O(3). A discussion of the foundation investigations and soil studies made to date and recommendations for future field explorations, laboratory investigations and design studies are also described in the same Appendix.

d. Discussion.- Certain sections of the dike will be constructed on clay areas. These sections were designed with slopes of 1 on 10, except at the Robertson Creek crossing where slopes of 1 on 20 were assumed. The sections on firm material were designed with slopes similar to those shown on Drawing BP-1-20/1 in Appendix III-24(1). Earth materials for the dike can be obtained from the Cornwall Canal and Lock excavation, and from borrow areas. It will be necessary to borrow all sand and gravel filter material and practically all rock for heavy riprap. Light riprap can probably be obtained from the earth embankment material.

e. Present Status of Plans.- Plans and specifications for the dike and drainage ditch have not been prepared, but estimates of quantity and cost for the dike were made. Before the location can be definitely established and the dike designed, surveys should be completed at the dike site and the future explorations, investigations, and studies recommended in Appendix III-O(3) carried out.

f. Estimated Cost and Time Required to Complete Plans.- It is estimated that the time required to complete the surveys and the recommended additional investigations of these dikes will be about three months. The cost of the additional subsurface exploration, surveying, and engineering is estimated at $7,500. Completion of the New Cornwall Canal Dike and drainage ditch is contemplated by the end of the first construction period, when the New Cornwall Lock will also be completed. The present lack of detailed plans for this phase will not interfere with the work schedule.

g. Estimated Cost.- The estimated cost is based on the total

cost of Canadian dikes as taken from the Engineering Estimate of June 1941, less the estimated cost of Bergen, Moulinette, and Mille Roches Dikes (Feature No. 25).

Cost of All Canadian Dikes, from Estimate of June 1941	$3,128,070
Deduct Contract Cost of Feature No. 25	139,473
Contract Cost of Feature No. 26	2,988,597
Engineering and Contingencies (about 25%)	746,403
Total Cost	$3,735,000

61. FEATURE No. 27 - RELOCATION OF CORNWALL CANAL.- a. Description and Purpose.- This item is necessary in order to continue existing 14-foot navigation during the later stages of construction of the Barnhart Island Powerhouse and to provide a waterway to the existing dockage areas at Cornwall, Ontario, after the completion of the proposed St. Lawrence River project. It is proposed to relocate a section of the existing Cornwall Canal between Lock 19 and Lock 20 and to construct a new lock and guard gate adapted to the new water level. For reasons set forth in paragraph 34b(13), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a new canal to replace that portion of the existing canal within the limits of the proposed site of the powerhouse, and a flight of two locks and a guard gate between the new upper pool, maximum elevation 249.0 and the existing lower pool at elevation 192.5. The new canal as originally planned started at the foot of Bergen Lake immediately south of Mille Roches (Transverse Mercator coordinates approximately N 1,831,300, E 372,200) and ran about 3,200 feet approximately S 86° 30' E; thence around a curve; and thence approximately S 52° 00' E, for about 9,300 feet to a connection with the existing canal at a point about 2,400 feet upstream of Lock 19 (Transverse Mercator coordinates approximately N 1,826,330, E 383,790). The total length of new canal was approximately 12,500 feet. The locks and guard gate were planned to be joined by a dike along the river side of the canal crossing Robertson's Creek and creating a pond of considerable size in the creek valley.

c. Discussion.- (1) Subsurface exploration disclosed that the area for a distance of about 900 feet on both sides of Robertson's Creek has an overburden of marine clay varying in depth from 30 to 50 feet. This clay deposit extends northward to the Canadian National Railway where it is about 20 feet deep. Therefore, foundation conditions in the section between the guard gate and the lock would be very unsatisfactory. A dike of approximately 60-foot height constructed on a 50-foot depth of soft clay would probably require side slopes of 1 on 20, which would be undesirable as well as costly. A concrete wall across Robertson's Creek, in lieu of the earth dike, or founding the dike on firm material by removal of the clay, would be still more costly. Further study disclosed that under the Original 238-242 Plan, a diversion canal would be needed

in order to maintain 14-foot navigation during construction of the powerhouse. The greater part of this diversion canal could be located along the center line of the new canal so as to become a part of the permanent installation. With the powerhouse in the new location now proposed, the existing canal will not be obstructed during construction of the powerhouse, and the temporary diversion canal will not be required.

(2) Because of the unfavorable foundation conditions encountered under the original plan and the fact that construction of the powerhouse in the new location will not interrupt navigation in the existing Cornwall Canal during the early stages of construction, a revision in the alignment of the new canal is proposed as follows:

> Beginning at a point (Transverse Mercator coordinates, N 1,828,500, E 379,230) about 1,500 feet downstream from Lock 20, and running approximately 5,058 feet, S 64° 33' E, to a point in the present Cornwall Canal (Transverse Mercator coordinates, N 1,826,330, E 383,799) located approximately 1,600 feet upstream of Lock 19. See Drawing BP-1-1/1, Appendix III-24(1).

The total length of reconstructed canal under this plan is about 5,058 feet as compared to 12,500 feet under the original plan. Additional studies indicate that it will be advantageous and more economical to combine the lock and guard gate into a single structure and use sector gates in the guard gate. The tentative location of the lock is such as to provide the most suitable alignment of the north forebay dike between the powerhouse and guard gate wall, and from the opposite guard gate wall toward the Canadian National Railway. This location avoids the deep clay area at Robertson's Creek and at the lower end of the proposed new lock.

(3) As recommended in Appendix III-O(3), final design has not been undertaken pending completion of foundation investigations and soil analyses along the route of the proposed new canal. Preliminary study indicated that side slopes of 1 on 2 will probably be satisfactory for the new canal, except where marine clay is encountered. After determining the shearing strength of the clay, analysis should be made to determine the side slopes. The bottom width of the canal will be 90 feet.

d. <u>Additional Work Required to Complete Plans.</u>- The following additional work is recommended:

(1) Further investigation and studies of foundation conditions, and further search for suitable materials; recommended additional subsurface investigations are outlined in Appendix III-O(3).

(2) Layout of the center line of the proposed relocated canal in accordance with Transverse Mercator coordinate system.

(3) Preparation of complete plans and specifications for canal.

e. Estimated Cost and Time Required To Complete Plans.- The time required to complete the additional work listed above is estimated at 6 weeks and the cost at $5,000.

f. Estimated Cost.- A summary of the estimated cost is given below:

Designation	Quantity (Cu. Yds.)	Unit Price	Amount
Excavation	696,000	.50	$348,000
Contract Cost			$348,000
Engineering and Contingencies (about 25%)			87,000
Total Cost			$435,000

62. FEATURE NO. 28 - NEW CORNWALL LOCK, GUARD GATE, AND PART OF ATTACHED DIKES.- a. Description and Purpose.- The items named are required to provide for 14-foot navigation via the relocated Cornwall Canal during the construction period and after creation of the pool to elevation 238. The lock will be adapted to the new water levels and will replace the existing Lock 20, which will be submerged. The proposed lock will be of a single lift type with integral sector guard gates founded on bedrock. No drawings have been prepared. For reasons set forth in paragraph 34b(13), P-1 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a flight of two locks and a separate guard gate between the new upper pool, maximum elevation 249, and the existing lower pool, elevation 192.5. Approximate location of the guard gate structure by Transverse Mercator coordinates was, N 1,830,000, E 378,570. Location of the lock was approximately, N 1,828,760, E 380,110. Under this plan the guard gate would be located about 1,000 feet above Robertson's Creek while the lock would be placed about the same distance below the creek.

c. Discussion.- (1) In view of the unsatisfactory foundation conditions in the vicinity of Robertson's Creek, and relocation of the powerhouse as discussed in paragraph 61c, a change in the location of the lock and guard gate was considered advisable. Further study indicated that the use of sector instead of miter gates will render an integral lock and gate structure advantageous and more economical. It is proposed to locate the lock so as to provide the most satisfactory alignment of the north forebay dike. The proposed location avoids the deep clay area at Robertson's Creek and at the lower end of the lock. Since the lock and guard gate will be required to operate the present system prior to the third stage of project construction, it is necessary that the sills for the upper lock gate and the guard gate be set at an elevation much lower than that required after creation of the final pool. This can be accomplished most economically by installation of upper lock gates divided horizontally so that the lower section could be kept closed after the pool is raised to final level,

and subsequently could be replaced with a permanent concrete sill. The sill and gate of the guard gate structure could be omitted until the pool is raised.

(2) A study was made of the locking time in the locks of the Cornwall Canal. The records available show the time of locking each boat, from the time that the bow enters to the time that the stern leaves the lock. The locking time varies generally from 12 to 50 minutes, with occasional instances of much longer periods due to lay-overs or accidents. Locks 15 and 17 require the longest period, being about equal for up-bound boats, but with Lock 17 requiring a much longer period for down-bound boats. The overall average for Lock 17, the highest for the system, is about 30 minutes. Due to the large number of records available, the periods were determined by inspection; the minimum and maximum time for up and downbound boats being listed for each of eight representatives pages of the 1938 record. Unusually high values which were apparently due to lay-overs or accident, or which were out of proportion, were not listed. The following tabulation shows the average locking time.

Lock No.	15	17	18	19	20	21
			UP-BOUND NAVIGATION			
Time Range (Minutes)	12-44	12-43	9-35	8-30	7-20	5-20
Average Minimum	14	14	11	10	10	8
Average Maximum	36	38	31	25	20	20
Average	25	26	21	18	15	14
			DOWN-BOUND NAVIGATION			
Time Range (Minutes)	12-41	11-68	9-35	8-30	7-36	5-38
Average Minimum	12	15	11	11	9	7
Average Maximum	33	52	23	19	30	25
Average	23	34	17	15	20	16
			BOTH DIRECTIONS			
Average Minimum	13	15	11	11	10	8
Average Maximum	35	45	27	22	25	23
Average	24	30	19	17	18	15

The reason for the longer period required for down-bound vessels through Lock 17 is apparently the narrow width of the lock, which is only 43 feet, 8 inches, or 1 foot, 4 inches less than that of any other lock from Montreal to Ogdensburg. The design of the new lock should be such that the

locking time will not be greater than that of the existing locks, in order that the time of travel through the canal will not be increased.

d. Present Status of Plans.- Final design has not been made pending completion of recommended foundation investigation of the new site. Based on one drill hole at the center line of pintles, the rock surface has been tentatively established at elevation 132. For report of field exploration see Appendix III-O(3). The additional investigations and surveys listed below should be made before final design of the lock and guard gate is undertaken.

(1) Layout of center line of the proposed lock in accordance with the Transverse Mercator system of coordinates.

(2) Additional subsurface investigations recommended in Appendix III-O(3).

e. Estimated Cost and Time Required to Complete Plans.- The time required to complete the preliminary work listed above and prepare the plans is estimated at 12 weeks, and the cost at $20,000. During this period excavation for the canal could proceed, and the work schedule need not be delayed.

f. Estimated Cost.- A summary of estimated cost is given below. A more detailed estimate is contained in Appendix III-O(3).

Cornwall Canal Lock and Guard Gate Structures	$5,374,425
Dikes	427,000
Contract Cost	$5,801,425
Engineering and Contingencies (about 21%)	1,218,575
	$7,020,000

63. FEATURE NO. 29 - RAILWAY AND HIGHWAY TO BARNHART ISLAND POWERHOUSE FROM CANADIAN SIDE.- a. Description and Purpose.- The Canadian end of the proposed powerhouse is located on a narrow strip of land between the North Channel of the St. Lawrence River and the Cornwall Canal. At present there are no connections to the powerhouse site from the Canadian mainland, except by foot over the canal lock gates. This work comprises proposed railroad connections from the Canadian National Railway and from the Ottawa Branch of the New York Central Railroad, and highway connection from Kings Highway No. 2 to the Barnhart Island powerhouse. A combined highway and railway bridge crossing Lock 19 is included. The highway will connect with Kings Highway No. 2 immediately north of Lock 19, and the railroad will connect with the Canadian National Railway and the Ottawa Branch of the New York Central Railroad near their intersection, about 1.5 miles northeast of Lock 19. The proposed facilities can also be used during the construction period. For reasons set forth in paragraph 34a, P-O priority has been assigned.

b. Treatment Under the Original 238-242 Plan.- The Original 238-242 Plan included a railroad spur from the Canadian National Railway at a point approximately 1/4 of a mile west of the crossing of the Otta-

wa Branch of the New York Central Railroad to the Canadian powerhouse. It was probably intended that the spur would also be available during construction. No details of the plan are available.

c. Discussion. Any plan involving crossing of the present Cornwall Canal by a low-level fixed bridge or on a fill, is unacceptable since traffic must be maintained on the canal during the construction period. A drawbridge at the site shown on the Original 238-242 Plan would be expensive and its construction would probably involve serious interferences with navigation. A high-level bridge would involve prohibitive grades. Consideration was given to passing the access road and railroad through a tunnel under the canal at approximately the site indicated in the 238-242 Plan. This could be built by out-and-cover methods during the first winter season of the construction period. It would give a complete separation of canal and land traffic. The only good alternate is a drawbridge crossing at Lock 19. A drawbridge at this site will be much shorter and cheaper than one crossing the canal prism. It will cause less interruption of canal traffic because of its location at a lock where all vessels necessarily stop. The largest items of land traffic at this crossing will be cement and concrete aggregate for the powerhouse and it is proposed that they be handled by a high-level belt conveyor or tramway which will not interfere with navigation. It is believed that the density of the remaining land traffic will not be so great that the presence of a drawbridge would be intolerable. A bobtail swing bridge at Lock 19 will not require any work to be done in the canal itself and there will be no interference with navigation during its construction. The fact that the bridge will be much cheaper than the tunnel and that it will be free from the expense and difficulty connected with drainage and snow removal in the tunnel scheme resulted in its adoption.

d. Recommended Plan.- Under the proposed plan the total length of railroad from the Canadian end of the powerhouse to the junction with the Canadian National Railway and the Ottawa Branch of the New York Central Railroad is approximately three miles. The length of the highway from the powerhouse to Kings Highway No.2 is about 0.9 mile. The railroad and highway can, during the construction, be extended across the downstream powerhouse cofferdam to Barnhart Island and the United States portion of the powerhouse, increasing the length of each by 1.25 miles. The portion of the railroad and highway between the powerhouse and Lock 19 will be on the existing earth fill along the river side of the present canal, 50 feet wide at the top with side slopes of 1 on $1\frac{1}{2}$. The minimum elevation of top of fill is 200, and the river side up to elevation 190 is protected with 1 foot of sand and gravel and 2 feet of riprap. The top width of 50 feet will provide 16 feet for the railroad on the river side and 34 feet for the 22-foot paved road with 6-foot shoulders on the canal side. A 15 degree curve is proposed for the railroad at the river side of the lock for the purpose of keeping the embankment from encroaching on the river. A bobtail, through truss, swing span is proposed for crossing the canal proper and a fixed, simple, through truss span for the weir section located landward of the lock, with an earth fill between the two bridges. The width of the roadway will be reduced to 20 feet at the crossing and the railroad track

will follow the center line of the road. A portion of the existing lock wall will be removed and the pivot pier of the swing bridge built in that space. The entire structure will be supported on pile foundation. The span across the weir section will be supported on piles at the banks of the canal. The abandoned lock between the two bridges will be filled. The roadway will then gradually widen to fifty feet, and provide two 11-foot paved roadways with 6-foot shoulders, separated by a 16-foot strip for the railroad. A crossover strip is provided for the two traffic lanes at the junction with Kings Highway No.2. The available width across the downstream powerhouse cofferdam to Barnhart Island is limited to thirty feet by the top width of the dike. It will, therefore, be necessary to include the railroad tracks within the highway pavement. A right-of-way for highway and railroad between the Canadian powerhouse and cofferdam "B" (located about 2,800 feet upstream from the powerhouse) will be provided for access to Barnhart Island, if desired, in connection with construction of Long Sault Dam.

e. Present Status of Plans.- Detailed plans for this feature have not been prepared. The layout of the railroad and highway between the powerhouse and Lock 19 was based on a plane-table survey by this office dated January 1942, and plotted to the scale of 1" = 200'. The portion between Lock 19 and the junction of the Canadian National Railway and the Ottawa Branch of the New York Central Railroad was based on a survey by the Department of Transport, Canada, entitled "Plan of Canadian Shore - Foot of Sheek Island to Cornwall", dated October 12, 1941 (scale 1" = 200'). The coordinates for the center line of pivot of the swing bridge were scaled from the map. Preliminary plans and profiles for this feature are contained in Appendix III-O(1). A detailed survey should be made along the proposed center line of railroad, and cross sections taken for quantity estimates. A detailed survey of Lock 19 is also necessary. This lock and the intersection of the Canadian National Railway and the Ottawa Branch of the New York Central Railroad should be coordinated with the Transverse Mercator system. Subsurface investigations should be made at sites of bridge piers and abutments, and fill sections along the canal. Construction plans and specifications should be prepared, including detail drawings of the junction of the connecting railroad and highway with the existing railroads and highway. Contract drawings for both bridges will be required.

f. Estimated Cost and Time Required to Complete Plans.- The time required to complete the preliminary work and prepare the plans is estimated at eight weeks, and the cost at $5,000.

g. Estimated Cost.- The estimated cost, which is included in Feature No. 24, is given below. A more detailed estimate is contained in Appendix III-O(3).

(1) Railway and Highway to Canadian Powerhouse

Contract Cost	$170,300	
Engineering and Contingencies (about 18%)	30,700	
Total Cost		$201,000

(continued)

(2) Bridges	Brt. fwd.	$201,000
Contract Cost	$303,378	
Engineering and Contingencies (about 21%)	63,622	
Total Cost		367,000
Grand Total		$568,000

64. FEATURE NO. 30 - RELOCATION OF CANADIAN NATIONAL RAILWAY.- a. Description and Purpose.- The Canadian National Railway is one of the principal transcontinental railroads in Canada. The double track main line which runs along the St. Lawrence River throughout the International Rapids Section will be flooded by the pool, from a point immediately west of Iroquois, Ontario, to a point immediately east of Mille Roches. The line will be relocated at higher elevation about $\frac{1}{2}$ to 1 mile north of the present location, as shown on Plate M-1. The work will involve the reconstruction of approximately 23 miles of first-class, double track railroad with all appurtenances, including three bridges. For reasons set forth in paragraph 34c(7), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included the foregoing relocation of this railroad. At the request of the Canadian Government, no further studies or plans have been made by this District.

c. Estimated Cost.- No new estimates of cost have been prepared. The estimated cost as set up in the Engineering Report of January 1941 is shown below.

Contract Cost, from report of January 1941	$2,750,000
Engineering and Contingencies (about 25%)	688,000
Total Cost	$3,438,000

65. FEATURE NO. 31 - RELOCATION OF KINGS HIGHWAY NO. 2.- a. Description and Purpose.- Kings Highway No. 2, a 20-foot improved highway is one of the principal roads of Canada. It parallels the St. Lawrence River throughout the International Rapids Section and will be flooded by the pool from a point approximately $1\frac{1}{4}$ miles west of Iroquois, Ontario, to a point near the proposed new lock in the Cornwall Canal, approximately $1\frac{1}{2}$ miles west of Cornwall, a distance of 26 miles. The highway will be relocated at higher elevation from $\frac{1}{2}$ to 2 miles north of the present location and will follow generally the relocated Canadian National Railway (Feature No. 30). The work will involve acquisition of the necessary right-of-way and the reconstruction of approximately 26 miles of first-class highway with all appurtenances, including three bridges. For reasons set forth in paragraph 34c(7), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The relocation of this highway was included in the Original 238-242 Plan. At the request of the Canadian Government, no further studies or plans have been made by this District.

c. Estimated Cost.- The estimated cost as taken from the

Engineering Report of January 1941, is given below:

Contract Cost, from report of January 1941	$1,700,000
Engineering and Contingencies (about 25%)	425,000
Total Cost	$2,125,000

66. FEATURE NO. 32 - CHANNEL IMPROVEMENTS BELOW BARNHART ISLAND POWERHOUSE.- a. Description and Purpose.- The river channel below the powerhouse will be improved by excavation in the powerhouse tailrace area and removal of the Crab Island Shoal immediately downstream therefrom. This work will provide greater discharge capacity, thus lowering the tailwater elevation at the powerhouse and providing additional head for power. The quantity of excavation will be governed by the cost of the work as compared with the value of the additional power. This feature has been assigned D (delayed) priority. Its completion will not be required until the final generator unit has been installed and the output of the powerhouse is approaching its ultimate capacity. Beginning of the work can be deferred until the entire project is substantially completed, without interference with the work schedule.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan provided for excavating the powerhouse tailrace and the river bed downstream therefrom, as shown on Plate M-II, to grade elevation 137. The area immediately below the powerhouse in the tailrace was included with the powerhouse excavation. The area downstream from the tailrace, designated as the Crab Island Shoal, included an estimated 1,462,930 cubic yards of dredging.

c. Additional Data Secured.- Soundings made by the United States Lake Survey in 1939-1940 indicate that the river bed is, in general, from one to three feet higher than previously shown. Therefore, the quantity of material to be removed will be considerably greater than previously estimated.

d. Status of Present Plans.- Since work will be deferred until the end of construction of the entire project, no study of this problem has been made. The feature has been extended to include the powerhouse tailrace outside the cofferdams, making the total estimated quantity of work about 1,900,000 cubic yards. However, it will be necessary, due to the recent soundings, to make a revised study of both the hydraulic and economic aspects of the feature. Subsurface investigations should be made to determine the character of materials to be excavated. In addition the hydraulic model tests planned for the river below Long Sault Dam to the foot of Cornwall Island should include a check of the hydraulic computations for this item.

e. Estimated Time Required to Complete Plans. - The aforementioned hydraulic and economic studies will require about three months. Subsurface investigations will be limited to obtaining only sufficient data to insure against inclusion of rock excavation, requiring the services of one probing rig and one seismic crew for about one month. Model tests will be included with those of the Cornwall Island North and South Channels (a high priority feature) and will be completed in ample time for use in the study.

f. Estimated Cost of Feature No.32.- The cost, including the investigations and engineering, is included in Feature No. 24. It is as follows:

Contract Cost	$1,929,380
Engineering and Contingencies (about 25%)	482,620
Total Cost	$2,412,000

67. FEATURE NO. 33 - IMPROVEMENT IN SOUTH CHANNEL BELOW MILE 107.4.- a. Description and Purpose.- This item comprises the channel improvement work south of Cornwall Island, Mile 107.4 to Mile 114.0, including the dredging at the mouth of Grass River but excluding the approach to Grass River Lock. The improvement of the South Channel between Cornwall Island and the United States mainland, to deep water in Lake St. Francis, is necessary for deep draft navigation and will also benefit power production by lowering the tailwater at the Barnhart Island Powerhouse. This improvement is interrelated with the Cornwall (North) Channel enlargement described under Feature No. 34. The outlines of the proposed improvements are shown on Drawing CC-R-1/1, Appendix III-O(1). For reasons set forth in paragraph 34o(12), P-2 priority has been assigned.

b. Treatment Under the Original 238-242 Plan.- Under the Original 238-242 Plan a channel 1,000 feet wide at grade elevation 121.0 was proposed from Mile 107.4 to Mile 109.8. From this point to Mile 114, a navigation channel 442 feet in width with grade elevation 124.0 was planned. These dimensions are interrelated with those of the Cornwall Channel Enlargement (Feature No.34). Subsidiary features of the original plan were the removal of the Roosevelt Bridge across the South Channel, the enlargement of the mouth of the Grass River to a width of 300 feet at grade elevation 140.0 and the construction of a training dike at its mouth to control cross currents. The criteria used in the design of the main channel and the improvement at the mouth of Grass River were not available.

c. Additional Data Secured.- Soundings through the greater part of this channel were taken by the United States Lake Survey in 1940. Measurements of surface current velocities throughout this channel and limited subsurface investigations at the principal work sites were made by this District. This additional information resulted in more accurate quantity estimates, and determination of the direction and velocity of flow and the kind of material likely to be encountered. The records of the subsurface explorations are contained in Appendix III-O(3).

d. Discussion.- (1) The basic problem is the enlargement of the restricted crooked and shallow South Channel to satisfy the criteria for navigation design discussed in Chapter II, and further enlargement of that portion from Mile 107.4 to 109.8 to the extent justified by the benefits to power resulting from the lowered tailwater at the powerhouse. The water levels of Lake St. Francis preclude the possibility of additional benefits to power from enlargement of the channel below mile 109.8; therefore, the channel from Mile 109.8 to Mile 114 will only require improvement for navigation. A further basic requirement

for navigation is the removal of the Roosevelt Bridge across the South Channel described under Feature No. 35. This bridge consists of fixed spans with insufficient vertical and horizontal clearances for deep draft navigation.

(2) An analysis of the hydraulic problems involved was not made due to insufficient time; consequently the plans for the work are tentative. Insofar as possible, the criteria for navigation channel design discussed in Chapter II were applied, but pending final hydraulic analysis, the proposed plan remains practically the same as that of the original plan. It is recommended that the final design for the South Channel be such that current velocities through the upper portion (Mile 107.4 to Mile 109.8) be reduced, if possible, to 4.0 feet per second in the interest of safe navigation. Alternate locations for the navigation channel were considered in an effort to eliminate or reduce its sharp reverse bends, but no satisfactory alternate alignment was found. It is considered that the best solution consists of improvement of the existing channel by easing the bends rather than construction of cutoffs, with the consequent complications due to cross currents. From Mile 109.8 to Mile 114 no change in river conditions is to be expected and the dredging of this channel can proceed at any time. The limited subsurface explorations indicate that all excavation should be performed with dipper dredges because of the presence of boulders. Satisfactory dumping grounds are available in Lake St. Francis off Hopkins Point, Ontario (Miles 118 to 120). See Plate M-1.

(3) The work schedule in South Channel from Mile 107.4 to Mile 109.8 is interrelated with that of the Cornwall (North) Channel enlargement on the opposite side of Cornwall Island (Feature No. 34). The stream velocities are high through both of these channels and the enlargement of the Cornwall (North) Channel will reduce velocities in the South Channel sufficiently to make dredging less difficult and dangerous, and more economical. It is, therefore, recommended that Feature Nos. 33 and 34 be combined into one contract. It is further recommended that the enlargement of the mouth of the Grass River be deferred until the excavation work in the South Channel, and the works at the entrance to Grass River Lock (Feature No. 20) are completed. This work could then be done to better advantage. The removal of the Roosevelt Bridge across the South Channel (Feature No. 35) is necessary before channel dredging can be completed.

e. Present Status of Plans.- Contract plans and specifications have not been prepared. Preliminary plans and estimates of cost have been developed and various studies carried out in order to arrive at the recommended solution. The additional preliminary work listed below should be completed before the final plans and specifications are prepared.

(1) Analysis of the hydraulic problems, and verification by hydraulic model tests.

(2) Additional subsurface exploration to determine the character of the material to be excavated and the elevation of ledge rock.

(3) A detailed survey for the purpose of obtaining cross sections, profiles, and underground data.

f. Estimated Cost and Time Required to Complete Plans.- The required subsurface explorations could be completed by four crews equipped with diamond drill rigs and sufficient floating plant, one crew operating a probing rig, and one seismic crew, in about 30 days during the navigation season. It is not recommended that the work be undertaken at other seasons because of ice jams which form in this reach. Detailed surveys should be made concurrently with subsurface exploration. After completion of the foregoing preliminary work, the time required to complete the plans and specifications will not exceed 60 days provided a similar schedule is adopted for the Cornwall Channel Enlargement (Feature No. 34). The estimated cost of completing the preliminary work and preparing the plans is as follows:

Hydraulic Model Study	$13,000
Subsurface Exploration	12,000
Detailed Survey	4,000
Plans and Specifications	2,000
Total Cost to Complete Preliminary Work	$31,000

g. Estimated Cost.- The estimated cost based on preliminary plans and subsurface investigations is given below. A detailed estimate of cost is included in Appendix III-O(3). The distribution of ordinary and swift water dipper dredging is based on the work schedule outlined in paragraph 34, and any change in that program may alter this estimate. The estimate given below includes the improvement at the mouth of Grass River, exclusive of the canal entrance.

Contract cost	$5,652,850
Engineering & contingencies (about 25%)	1,413,150
Total Cost	$7,066,000

68. FEATURE NO. 34 - CORNWALL CHANNEL ENLARGEMENT.- a. Description and Purpose.- Work comprises channel improvement north of Cornwall Island and downstream from Pollys Gut. Enlargement of the channel is proposed in order to reduce velocities south of Cornwall Island for the benefit of navigation, and to lower the elevation of the tailwater at the Barnhart Island powerhouse. The cross-sectional area to be provided is interrelated with the improvement of the South Channel (Feature No. 33). The basic problem is the design of a channel north of the island, which when considered in conjunction with the South Channel, will result in maximum benefits for power and navigation, commensurate with the cost of the work. It will include the removal of a sill in the North Channel which controls the river levels at the head of Pollys Gut, where the river divides to form the North and South Channels around Cornwall Island. The outlines of the proposed improvement are shown on Drawing CC-R-1/1, Appendix III-O(1). For reasons set forth in paragraph 34c (13), P-2 priority has been assigned.

b. Treatment Under the Original 238-242 Plan.- Under the

Original 238-242 Plan a straight cut was included for about one mile through the North Channel having a width of 600 feet at grade elevation 131.0. These dimensions are interrelated with those for the South Channel improvement. No records are available pertaining to the criteria used in the design of this channel, but apparently the grade was set at elevation 131.0 in order to avoid excavation of excessive ledge rock.

c. Additional Data Secured.- The recent and more comprehensive soundings through this channel taken by the United States Lake Survey in 1940 show considerably higher bottom elevations than anticipated when the original plans were made. Subsurface investigations made by this District established more definitely the presence of ledge rock in this vicinity. A survey of surface current velocities through this channel was made by this District in 1941. A description of the method and results of the subsurface investigations are shown on Drawings CC-A-2/1-5, Appendix III-O(3).

d. Discussion.- An analysis of the hydraulic problems involved was not made due to insufficient time. It should be made in conjunction with the improvement of the South Channel. The plans presented are tentative only. It is not intended that this channel will be used for navigation, but its improvement will affect the velocities in the navigation channel south of Cornwall Island. Pending final hydraulic analysis, the proposed plan remains practically the same as that of the original plan. However, the discovery of additional shoals has made it advisable to lengthen the improvement sufficiently to obtain the same width and grade throughout the area. No change in river conditions is to be expected and the dredging of this channel can proceed at any time. The explorations indicate that all work in the river channel will be performed by dipper dredge because of the character of the material. A certain amount of excavation in the dry might be performed where the bank is to be cut away, but disposal of such material on the north side of the river is not considered practical because of the proximity of the industrial area of the City of Cornwall, Ontario. It is, therefore, recommended that all material be disposed of by rehandling and transporting to available disposal areas in Lake St. Francis opposite Miles 118 to 120. It is further recommended that the dredging of this channel be completed prior to dredging the South Channel between Mile 107.4 and Mile 109.8 (Feature No.33) because the reduction of the high velocities in this channel will result in more rapid and less costly dredging.

e. Present Status of Plans.- Contract Plans and specifications have not been prepared. Preliminary plans and estimates of cost have been developed and various studies carried out in order to arrive at the recommended solution. The additional preliminary work listed below should be completed before the final plans and specifications are prepared.

(1) Analysis of the hydraulic problems and verification by hydraulic model tests.

(2) Additional subsurface explorations to determine the

character of the material to be excavated and the elevation of ledge rock.

(3) A detailed survey for the purpose of obtaining cross sections, profiles, and underground data.

f. Estimated Cost and Time Required to Complete Plans.- The analysis of the hydraulic problem will require about 30 days. By using the maps and other data now available, the channel dimensions obtained by computations could be verified in about 60 days by an established hydraulic laboratory. The required subsurface explorations could be completed by three crews equipped with diamond drill rigs and sufficient floating plant in about 30 days during the navigation season. Attempts to accomplish this work during winter or early spring are not advisable because of the dangers and difficulties resulting from ice conditions. Detailed surveys should be made concurrently with the subsurface explorations. After completion of the foregoing preliminary work, the time required to complete the plans and specifications will not exceed 60 days provided similar schedules are adopted for the improvement of the South Channel (Feature No. 33). The estimated cost of the preliminary work and preparation of plans and specifications is given below:

Hydraulic Model Study..........	$6,000
Subsurface Exploration.........	5,000
Detailed Survey................	1,000
Plans and Specifications.......	2,000
Total Cost to Complete Preliminary Work..........	$14,000

g. Estimate of Cost.- The estimated cost based on preliminary plans and surveys and subsurface investigations is given below. A detailed estimate of cost is included in Appendix III-O(3). The distribution of the various types of excavation is based on the work schedule outlined in paragraph 34, and any change in that program may alter this estimate.

Contract cost.............................	$1,871,220
Engineering & contingencies (about 25%)...	467,780
Total Cost.........................	$2,339,000

69. FEATURE NO. 35 - RELOCATION OF OTTAWA BRANCH OF THE NEW YORK CENTRAL RAILROAD AND ROOSEVELT HIGHWAY.- a. Description and Purpose.- This comprises all work in connection with the relocation of the Ottawa Branch of the New York Central Railroad and an existing toll highway, which cross the South Channel on a combined bridge located north of Rooseveltown, New York. The following items are included:

(1) The construction of a single track railroad equivalent to the existing line with alignment described below under "Recommended Plan."

(2) The construction of an improved highway following the same general alignment as the relocated railroad.

(3) The construction of a new combined highway and railroad bridge across Grass River and a similar structure across Pollys Gut.

(4) Removal of the existing bridge across the South Channel.

For reasons set forth in paragraphs 34a, and 34c(7) the portion pertaining to completion of the relocated railroad and highway to the Grass River lock has been given P-0 priority, and the remainder has been assigned P-2 priority.

b. Treatment Under the Original 238-242 Plan.- The Original 238-242 Plan proposed similar relocations with the same general alignment as now considered. Studies of the original plan have indicated that relocation of the routes is preferable to construction of a new bridge across the South Channel, at or near the present site.

c. Discussion.- The existing bridge across the channel south of Cornwall Island does not have sufficient horizontal and vertical clearances for navigation in the proposed 27-foot channel. It will, therefore, be necessary either to construct a new bridge at approximately the same location as the present structure, or relocate the highway and railroad so as to permit the removal of the existing bridge. Relocation is recommended as being the most satisfactory from the standpoint of navigation. Navigation interests maintain that the construction of a low level bridge across the South Channel in the vicinity of the present structure is objectionable because of swift currents which would exist in the vicinity, even after completion of the proposed hydraulic cuts in the North and South Channels (Features Nos. 33 and 34). Removal of the existing bridge is, therefore, considered advisable. Studies of a high level bridge at the same location indicated that the cost would be excessive.

d. Recommended Plan.- The exact alignment of the relocated railroad has not been established. In general, it is proposed to start from the existing line immediately north of the Racquette River bridge and continue in a westerly direction to a bridge site on Grass River about 3/4 mile upstream from its mouth. A combined railroad and highway bridge with 50-foot vertical clearance is proposed at this location. The relocated railroad will then continue in a northerly direction along the top of Dikes Nos. 7 and 8 and across the westerly end of Grass River Lock on a combined railroad and highway bobtail, swing, drawbridge. The relocated railroad will then continue in an easterly direction to Pollys Gut, which it will cross on a combined railroad and highway bridge, and then continue in an easterly direction to the existing line south of the present bridge over the channel north of Cornwall Island. The portion of the roadbed on Dikes Nos. 7 and 8, and the construction of the drawbridge across the lock, will be included in the lock contract. The plan for the relocated highway has not been fully developed, but in

general it is proposed to start from the existing road at a point north of Rooseveltown; thence in a westerly direction approximately 4,000 feet to a junction with an existing secondary road which leads to the vicinity of the Grass River bridge site. This secondary road will be improved and the relocated highway will cross the combined Grass River bridge. It will then continue along the top of Dikes Nos. 7 and 8 and across the combined Grass River lock bridge, thence paralleling the new alignment of the relocated railroad to the combined bridge across Pollys Gut, and thence easterly to a junction with the existing highway on Cornwall Island.

e. Present Status of Plans.- No plans have been made for removal of the existing bridge over the South Channel. Tentative locations for the various items of this feature have been established from available topographic maps and field reconnaissance. See Drawings CMRR-1-1/1-8 and CMHN-1-1/1-7 in Appendix III-O(1). The area between Rooseveltown and the Grass River Bridge has been surveyed (see Drawings MBR-1-551/1-3 in the District File); holes have been drilled at the Grass River Bridge site, and results are shown on Drawing CMRR-1-2/1, Appendix III-O(1). Surveys and plans, including specifications and analyses of design, have been completed for the Grass River Lock and Dikes Nos. 7 and 8, but the area between Dike No. 8 and Pollys Gut has not been surveyed by this District; the Pollys Gut bridge site has not been definitely established, but holes have been drilled at one location and the results are shown on Drawing CMRR-1-2/2, Appendix III-O(1); the area on Cornwall Island between Pollys Gut and the existing railroad and highway has not been surveyed. An analysis of design of the relocation of the railroad and highway is presented in Appendix III-O(3). The surveys should be completed before the most economical location for the highway and railroad can be determined and the plans and specifications completed. The additional data for the area north and east of Grass River Lock and on Cornwall Island can be obtained during the early stages of construction. However, the field work for that portion of the feature between Rooseveltown and Grass River Lock should be expedited in order that the plans and specifications can be prepared and a contract awarded at an early date.

f. Estimated Cost and Time Required to Complete Plans.- It is estimated that three months will be required to complete the preliminary work, exclusive of the design of the bridges. It is proposed that the bridges be designed by the contractor or a consultant. The estimated cost to complete the preliminary work, exclusive of the bridge plans, is $7,500.

g. Estimated Cost.- A summary of the estimated cost is given below. A detailed estimate of the cost of relocation of the Ottawa Branch of the New York Central Railroad, and highways, is contained in Appendix III-O(3).

(1) Railroad and Highway Relocation

Contract Cost	$418,160	
Engineering and Contingencies (about 21%)	87,840	
Total Cost		$506,000

(continued)

Brt. fwd. $506,000

(2)	Grass River Bridge		
	Contract Cost	$593,360	
	Engineering and Contingencies (about 21%)	124,640	
	Total Cost		718,000
(3)	Pollys Gut Bridge		
	Contract Cost	640,600	
	Engineering and Contingencies (about 21%)	134,400	
	Total Cost		775,000
(4)	Removal of Roosevelt Bridge		
	Contract Cost	$94,500	
	Engineering and Contingencies (about 21%)	20,500	
	Total Cost		115,000
	Grand Total		$2,114,000

70. FEATURE NO. 36 - RELOCATION OF TRANSMISSION LINES OF ST. LAWRENCE RIVER POWER COMPANY.- a. Description and Purpose. A double-circuit, steel-tower, 110 kv. transmission line delivers power from Cedar Rapids, Ontario, to the Aluminum Company at Massena, and a single-circuit, wood-pole, 110 kv. transmission line following the same right-of-way delivers power from the Ontario Hydro network to the same company. The portions of these lines which are within the United States are owned by the St. Lawrence River Power Company. See Plate M-I and Drawing No. MBT-1-1/1, Appendix III-O(1). There is also a private telephone line on the same right-of-way. These lines cross the westerly end of Robinson Bay Lock site, and several of the poles and towers will be surrounded by water in the powerhouse forebay. It is, therefore, necessary to either raise the lines near their present location, or relocate them and provide the necessary clearance where they cross natural or artificial waterways. For reasons set forth in paragraph 34c(14), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included a lump sum price for relocation of these lines, but plans for the work were not developed.

c. Discussion.- Several plans were studied which included the raising of the present line as compared to various relocations. The location of these alternate routes is shown on Drawings Nos. MBT-1-1/2 and MBT-1-1/4. The following table shows the cost of the best alternate route (No. 5) and the cost of raising the lines in their present location (Route No. 4) for spans of 1,000, 1,200 and 1,500 feet:

Route	Tower Spacing	Estimated Cost
5	-	$164,000
4	1000	223,000
4	1200	213,000
4	1500	198,000

d. Recommended Plan.- Relocation Route No. 5 is the most economical and has the further advantage of not having towers located in the forebay in the vicinity of navigation which is inherent in Route No. 4 See Drawing MBT-1-1/4. The design of the towers has not been developed, but in general it is planned to carry the three circuits ground wires, and telephone circuit on the same steel structures. Because of the high cost of foundations, long spans are cheaper than ordinary spans. The vertical clearances proposed are Long Sault Canal, 170 feet; forebay, 75 feet; and Cornwall Canal, 150 feet above ultimate high water which is assumed at elevation 249. It is proposed to extend the foundations 10 feet above the water surface to protect the steel from ice.

e. Present Status of Plans.- Additional study is required before contract drawings and specifications can be prepared. The plan for maintaining service during construction of the two new towers required at Robinson Bay lock is shown on Drawing No. MBT-1-1/3, Appendix III-O(1). The design of these towers has not been made. Further subsurface explorations will be required at tower sites to determine the proper depth and area of foundations.

f. Estimated Cost and Time Required to Complete Plans.- It is estimated that three months will be required to complete the studies and prepare the plans for this work and the cost of the preliminary work is estimated at $10,000.

g. Estimated Cost.- A summary of the estimated cost is shown below. A detailed estimate is contained in Appendix III-O(3).

(1)	Raising Transmission Line at Robinson Bay Lock		
	Contract Cost	$31,856	
	Engineering and Contingencies (about 21%)	7,144	
	Total Cost		$39,000
(2)	Forebay Relocation		
	Contract Cost	$103,770	
	Engineering and Contingencies (about 21%)	21,230	
	Total Cost		$125,000
	Grand Total		$164,000

71. FEATURE NO. 37 - LANDS AND EASEMENTS IN THE UNITED STATES.- a. Description and Purpose.- Lands on the United States side are required for most of the project features, for camp sites, construction areas, connecting roads and flowage areas. The property involved consists, for the most part, of farms and summer cottages and also includes the hamlet of Massena Center (about 30 properties), the settlement of Louisville Landing (about 25 properties, the majority of which are summer camps), and a portion of the Village of Waddington (Feature No. 10.). Lands for each feature of the project will be required at the beginning of construction of the feature, and in general it will have the same priority as the feature. Lands needed for construction camps, connecting

routes and the features having P-O priority will be required immediately upon authorization of construction of the project and should therefore have P-O priority. Because of local conditions, it is considered that all of the land lying between the Grass River and the St. Lawrence River, and between the Massena Power Canal and Pollys Gut, including Long Sault and Barnhart Islands, should be acquired at the beginning of construction, and this acquisition has been assigned P-O priority.

b. Treatment Under the Original 238-242 Plan.- No details are available as to the basis for land estimatesin the original plan. It appears that the estimates for both acreage and cost were based upon a general reconnaissance and upon a general basic unit price for value of lands and value of improvements. It also appears that this estimate included merely lands required for project features and flowage, without giving consideration to areas that might be necessary for camp sites, spoil banks, and other auxiliary features.

c. Additional Data Secured.- A considerable portion of the project area has been covered by new topographic surveys and an aerial survey, and the maps of the "Ross Survey" have been obtained and made available for use in land work. (See Chapter II, paragraphs 11c (3) and (12).) The additional surveys have been used in the studies of land required for the project. Deed descriptions and other data pertaining to numerous parcels have been obtained from County records. Numerous appraisals have been made and data collected to determine the current value of property.

d. Discussion.- In the land studies, full consideration has been given to the proposed village site, camp sites, construction areas, connecting roads, railroad relocations, etc., in addition to areas which will be actually occupied by project features and will be required for flowage. The investigations were detailed and made with the intent of immediate acquisition of the properties. The extent of these investigations is discussed in Chapter II, paragraph 15. In certain sections where this work has been practically completed, particularly in the area between Point Rockway and Leishmans Point, revisions may be necessary if final designs indicate that insufficient areas have been covered. However, in such areas, basic information has been secured and revisions can be readily made. The investigations were carried on concurrently with design studies, and taking lines were established upon the basis of information available at the time.

e. Recommended Plan.- It is proposed to acquire in fee all of the land on the United States side occupied by structures or required for construction purposes; to acquire in fee or by an unrestricted flowage easement all lands required for flowage; and to acquire the necessary easements for all highway and railroad relocations outside of the construction and flowage areas. The construction areas include all of Barnhart and Long Sault Islands and all of the area bounded by the Grass River, the Massena Canal and the St. Lawrence except the lands actually occupied by the plants of the Defense Plant Corporation and the Aluminum Company of America and their planned extensions, and portions of the north bank of Grass River. They also include most of all of the land

north of the Point Rockway Canal and considerable areas needed for borrow pits and spoil banks. The taking lines should generally involve the acquisition of entire farms rather than taking a portion and paying severance damages. In the flowage areas when the shore of the new pool is not occupied by dikes or other structures, or by construction areas, it is believed that the shore line should be left in private ownership to encourage an increase in the existing development of cottages and resorts. It is therefore proposed that the flowage area be acquired in fee up to elevation 230 and that an unrestricted flowage easement be acquired between elevation 230 and elevation 250.

f. Estimated Cost.- The estimated cost of acquiring the lands which have been assigned P-0 priority is $1,000,000, and the total estimated cost of acquiring necessary lands and easements on the United States side is $6,200,000. The estimate includes legal costs, the cost of rehabilitation of Waddington, New York (Feature No. 10), and other incidental expenses.

72. FEATURE NO.38 - LANDS AND EASEMENTS IN CANADA.- Under the terms of the International Agreement, acquisition of lands in Canada would be the respoinsibility of the Canadian Government, and therefore no investigation of this feature has been made. The greater portion of the lands on the Canadian side will be required for rehabilitation purposes, flowage, and highway and railroad relocations, and only a small percentage for the project features. The estimated cost of land acquisition on the Canadian side, exclusive of the rehabilitation of Iroquois and Morrisburg, Ontario, as taken from the Engineering Report of January 1941, and used by this District, is given below.

Estimated Cost, from report of January 1941	$12,454,340
Engineering and Contingencies (about 12%)	1,556,660
Total Cost	$14,011,000

73. FEATURE NO.39 - CLEARING OF FLOWAGE AREAS.- a. Description and Purpose.- Work includes the clearing of all trees, fences, brush, buildings, and other undesirable material from the entire flowage basin below elevation 249 (extreme flood line), from Chimney Point to the Barnhart Island powerhouse, estimated at 8,242 acres. The general areas to be cleared are shown on sheet SX-1-1/1 in Appendix III-O(1). For reasons set forth in paragraph 34c(15), P-2 priority has been assigned.

b. Treatment under the Original 238-242 Plan.- The Original 238-242 Plan included this work, and the estimate included lump sums for clearing on the Canadian and the United States sides.

c. Discussion.- Of the total of 8,242 acres to be cleared, 2,592 would be located in Canada and 5,650 in the United States. Aerial photographs covering the proposed project were used in preparation of the plan showing the areas to be cleared (SX-1-1/1, Appendix III-O(1).) Detailed study will be required to determine accurately the class of clearing, as well as the number of buildings. Studies should be made as to the possibilities of salvage. On Barnhart and Croil Islands, there is first growth

timber, which will be of value for construction purposes. With the exception of clearing included in specific construction contracts, which would ordinarily be done by the contractors, the clearing of flowage areas will be performed under separate clearing contracts. The clearing line at elevation 250 must be staked in the field before clearing is undertaken, and it is intended that one or more field survey parties will be continuously employed on this work during clearing operations.

d. Estimated Cost.- The cost as given in Engineering Estimate of June 1941 is shown below:

Cost from Estimate of June 1941	$400,000
Engineering and Contingencies (about 25%)	100,000
Total Cost	$500,000

The total cost is divided between the United States and Canada about as follows:

Canada

Estimated Cost	$53,200
Engineering and Contingencies (about 25%)	$13,300
Total Cost	$66,500

United States

Estimated Cost	$346,800
Engineering and Contingencies (about 25%)	86,700
Total Cost	$433,500

74. PREVIOUS ESTIMATES.- a. Joint Board Engineering Report Estimate of January 3, 1941.- The Canadian Temporary Great Lakes - St. Lawrence Committee and the United States St. Lawrence Advisory Committee submitted a joint report to the President of the United States and the Prime Minister of Canada on January 3, 1941, recommending the "238-242" Controlled Single Stage Project. It was accompanied by an engineering report made by the Joint Board of Engineers which had been studying the matter under the direction of the Advisory Committees. (See Chapter I, paragraph 9b.) This engineering report presented an outline and estimate of cost of the "238-242" Plan. This plan, referred to in this report as the Original 238-242 Plan, was subsequently incorporated in the International Agreement of March 19, 1941, and became the basis of all subsequent studies by this District. The estimate of cost was printed in full by the Canadian Government in a document entitled "St. Lawrence Deep Waterway International Rapids Section, Reports submitted to the President of the United States and the Prime Minister of Canada by the Canadian Temporary Great Lakes - St. Lawrence Basin Committee and the United States - St. Lawrence Advisory Committee, Ottawa, Canada, January 3, 1941." The following summary is taken from that publication, and the detailed estimate is shown in Appendix IV-O.

TABLE 4

SUMMARY OF ESTIMATE

INTERNATIONAL RAPIDS SECTION - JANUARY 3, 1941

A.- Works Solely for Navigation.		
I. Upper Pool - at Point Rockway Locks	$ 7,497,000	
II. Lower Pool - Long Sault Canal and Dikes	31,081,000	
		$38,578,000
B - Works Primarily for Power		
I. Substructures, head and tailrace excavation	41,624,000	
II. Machinery and Superstructures		
1. Machinery	50,328,000	
2. Superstructure	4,852,000	
		96,804,000
C - Works Common to Navigation and Power		
1. Channel excavation	48,136,000	
2. Ice cribs above Prescott and above Galop Island	656,000	
3. Iroquois Dam	7,310,000	
4. Dikes	12,374,000	

(Cont'd)

TABLE 4 (Cont'd.)

SUMMARY OF ESTIMATE

INTERNATIONAL RAPIDS SECTION - JANUARY 3, 1941

5.	Supply channel and weir at Massena	2,363,000	
6.	Diversion cut through Long Sault Island	2,569,000	
7.	Main Long Sault Dam	20,055,000	
8.	Guard Gate, 14-foot Lock and Weir at Maple Grove	2,624,000	
9.	14-foot Lock and Dikes at Iroquois	604,000	
10.	Railroad relocation	3,696,000	
11.	Clearing pool	518,000	
12.	Rehabilitation of Morrisburg	5,024,000	
13.	Rehabilitation of Iroquois	3,379,000	
14.	Acquisition of lands, etc., U.S. side	4,657,000	
15.	Acquisition of lands, etc., Canadian side	14,011,000	
16.	Highway relocation	2,812,000	
			130,788,000
	GRAND TOTAL........................		$266,170,000

b. United States Engineer Department Estimate of June 1941.- Circumstances made it necessary that the Joint Board submit its report on January 3, 1941, although it was known at that time that preliminary studies then in progress in this District, particularly the pending preliminary report on powerhouse location and layout which then had been nearly completed by the Harza Engineering Company, would furnish additional data from which a much more complete estimate could be made. Such a revised estimate was completed by the District early in June 1941, incorporating the results of the new work and showing the division of costs between the United States and Canada as prescribed by the International Agreement of March 19, 1941. The total amount of this estimate was $287,981,000. During the hearings on the St. Lawrence Project held by the Rivers and Harbors Committee of the House of Representatives in 1941, the testimony submitted by the Corps of Engineers as to the cost of the project was based on this estimate. As a result of the aforementioned preliminary studies and investigations by this District, changes in the design and character of several structures were adopted. These changes, together with a revision of unit prices to anticipate the continuing rise of construction costs to July 1, 1941, accounted for the variation of the June 1941 estimate from that of the Joint Board Report of January 3, 1941. The principal variations were:

(1) Revision of the Plans for the Iroquois Dam.- The plans for the Iroquois Dam have been revised to provide a continuous

sill structure to be constructed within cofferdams instead of individual pier construction by caisson. Preliminary field investigations indicated the overburden on the bed of the river to be extremely variable, both in depth and character, and that a continuous sill structure would be better suited to the foundation conditions. Although the estimated cost of the revised structure exceeded the January 3, 1941 estimate for the original structure, it was believed that under existing foundation conditions as shown by the more recent investigations, the caisson method of construction would result in a less satisfactory structure and would be equally as costly.

(2) Relocation of the Long Sault Dam.-The Long Sault Dam was relocated a short distance downstream; resulting in a shorter structure, reduction of the number of gates from 60 to 40, lowering of the gate sills, and in considerable reduction in cost.

(3) Reduction of Cross Section of Dikes.-The cross section of the dikes was generally reduced from a 50-foot crown with 1 on 4.5 side slopes to a 30-foot crown with 1 on 3 side slopes. This resulted in a large reduction in embankment quantities.

(4) Reclassification of Excavation Quantities.-Current preliminary investigations indicated that excavation quantities should in a large measure be reclassified. The reclassification effected a decrease in cost.

(5) Preparation of Working Drawings for 27-foot Locks.-Quantity estimates from working drawings of the 27-foot locks showed an increase in concrete quantities and corresponding increase in cost.

(6) 14-Foot Canal and Lock Structures.-The two 14-foot locks of the New Cornwall Canal were redesigned as a single lock of high lift. Computations based on this design showed an increase in quantities and cost.

(7) Revision of Unit Prices- Unit prices were adopted to anticipate the continuing rise in construction costs, in conjunction with the excess cost expected to result from expediting the work as a defense item. In general, unit prices were higher than those used in the January 3 estimate. In two items, dry earth excavation and embankment, prices were lowered after study of the layout indicated that more economical methods could be used.

(8) Increased Price of Electrical and Mechanical Equipment.-New quotations from manufacturers showed a great increase in the cost of electrical and mechanical equipment above quotations made 2 or 3 years earlier, on which the January 3 estimate was based.

(9) Land Costs.- A study of current values of United States lands resulted in a lower estimate.

The estimate of June 1941 is contained in full in Appendix IV-O. A summary of this estimate is given in Table 5, and the comparative quanti-

ties for the January and June estimates for those items for which quantities were of such magnitude as to be of real importance, are given in Table 6. Table 7 shows comparative unit prices.

TABLE 5

United States Engineer Department Estimate of June 1941

	Canada	U.S.	Totals
A - Works solely for Navigation.			
I. Upper Pool		$10,967,000	
II. Lower Pool		37,890,000	$48,857,000
B - Works primarily for Power.			
I. Structures, head and tailrace excavation		40,600,000	
II. Machinery and equipment .	$37,950,000	37,950,000	116,500,000
C - Works common to Navigation and Power.			
1. Channel excavation. .		44,291,000	
2. Ice Cribs.		514,000	
3. Control dam at Iroquois Point		11,071,000	
4. Dikes		6,210,000	
5. Supply channel and weir at Massena.		2,085,000	
6. Diversion cut through Long Sault Island . . .		2,217,000	
7. Main dam at Long Sault Rapids		16,063,000	
8. Guard gate, 14-foot lock, and weir at Maple Grove		4,149,000	
9. 14-foot lock and dikes at Iroquois.		604,000	
10. Railroad relocation . .		3,646,000	
11. Clearing pool		500,000	
12. Rehabilitation of Morrisburg	5,024,000		
13. Rehabilitation of Iroquois	3,379,000		
14. Acquisition of lands in U.S.		6,200,000	
15. Acquisition of lands in Canada	14,011,000		
16. Highway relocation .		2,660,000	122,624,000
TOTALS	$60,364,000	227,617,000	287,981,000

TABLE 6

COMPARISON OF QUANTITIES IN ESTIMATES OF JANUARY 3, 1941 AND JUNE, 1941

	Joint Board Estimate of January 3, 1941									United States Engineer Department Estimate of June, 1941								
	Concrete	EXCAVATION					FILL			Concrete	EXCAVATION					FILL		
	(All Classes) c. y.	Earth, Dry c. y.	Earth, Wet c. y.	Rock, Dry c. y.	Rock, Wet c. y.	Total Exc. c. y.	Earth c. y.	Rock c. y.	Total Fill c. y.	(All Classes) c. y.	Earth, Dry c. y.	Earth, Wet c. y.	Rock, Dry c. y.	Rock, Wet c. y.	Total Exc. c. y.	Earth c. y.	Rock c. y.	Total Fill c. y.
Iroquois Dam and Dikes *	120,260	124,310		7,060		131,370	83,720	241,340	325,060	254,500	448,000		24,900		472,900	210,000	96,000	306,000
Point Rockway Canal		3,292,560	320,500			3,613,060	1,002,770	63,740	1,066,510		2,992,700	255,000			3,247,700	668,200	43,700	711,900
Point Rockway Lock & Dikes	141,960	260,000				260,000				353,784	1,224,805		43,854		1,268,659	1,387,559		1,387,559
Massena Canal Intaka & Dikes *	101,220	1,220,460	46,000	6,050		1,272,510	1,843,600	185,990	2,029,590	91,210	1,026,144	120,700	5,930		1,152,774	832,768	61,371	894,139
Long Sault Canal & Dikes	13,880	5,924,900	1,223,000			7,147,900	4,096,940	112,500	4,209,440		5,743,300	1,269,800			7,013,100	7,008,900	553,233	7,562,133
Long Sault Cuard Gate & Dikes	42,600	42,550				42,550				97,957	571,892				571,892	242,915		242,915
Robinson Bay Lock & Dikes	420,520	878,530				878,530				522,524	1,876,522		30,565		1,907,087	2,135,859		2,135,859
Crass River Lock & Dikes	351,060	1,296,950				1,296,950				363,360	1,929,092		28,340		1,957,432	1,630,702		1,630,702
Long Sault Dam & Dikes *	818,630	3,607,270	317,500	145,900		4,070,670	339,530	48,840	388,370	642,400	2,997,789	350,000	287,800		3,635,589	223,954	18,002	241,956
Miscellaneous Dikes		571,390				571,390	5,247,480	663,180	5,910,660		433,110				433,110	6,014,458	219,549	6,234,007
Naw Cornwall Lock and Cuard Cate	98,340	865,390				865,390				172,535	405,533		13,608		419,141	743,307		743,307
Channel Excavation common to Navigation and Power		13,894,360	23,087,620	3,477,200	418,370	40,877,550					21,885,100	15,606,700	2,879,600	402,550	40,773,950			
Barnhart Is. Powerhouse including Tailrace Excavation, Crab Is. Shoal Excavation, and South Forebay Dike *	1,493,540	5,419,760	2,307,490	586,750		8,314,000	1,578,480	126,600	1,705,080	1,509,000	7,493,200	1,837,500	497,620		9,828,320	697,775	48,210	745,985
Totals	3,602,010	37,398,430	27,302,110	4,222,960	418,370	69,341,870	14,192,520	1,442,190	15,634,710	4,007,820	49,027,187	19,439,700	3,812,217	402,550	72,681,654	21,796,397	1,040,065	22,836,462

* Does not include cofferdams.

TABLE 7

COMPARISON OF UNIT PRICES
(exclusive of 25% for Engineering and Contingencies)

	Jan. 3, 1941 Joint Board	June 1941 U. S. E. D.
Mass concrete in locks	$ 10.00 c.y.	$ 10.00 c.y.
Mass concrete in dams)		10.00 c.y.
Pier concrete in dams)	12.00 c.y.	18.00 c.y.
Bridge concrete in dams)		30.00 c.y.
Concrete in powerhouse substructure .)	15.00 c.y.	16.00 c.y.
Rock excavation, dry	1.60 c.y.(1)	1.60 c.y.(1)
Rock excavation, wet	4.25 c.y.(1)	4.75 c.y.(1)
Common excavation, dry	0.65 c.y.(1)	0.50 c.y.(1)
Common excavation, wet	0.90 c.y.(1)	1.05 c.y.(1)
Lock excavation, common	0.65 c.y.	0.65 c.y.
Embankment	0.90 c.y.(1)	0.50 c.y.(1)
Riprap	1.00 to 2.00	1.50 to 2.00
Dam gates	13.00 sq. ft.	15.00 sq.ft.
Structural steel for lock gates and similar work	(2)	0.10 lb.
Lock backfill	(3)	0.40 c.y.
Cofferdam and diversion at Long Sault Dam	$5,755,370 lump sum	$5,083,000 lump sum

(1) Usual price, but some exceptions.
(2) Not known, but overall gate estimates agree fairly well with U.S. estimates.
(3) No estimate shown; probably included in unit price for excavation.

75. BASIS OF NEW ESTIMATES.- New detailed estimates have now been prepared, based upon completed design of a number of major structures and other changed conditions, as discussed below, and incorporating the results of work from June 1941 to May 1942. Estimates on some features for which contract plans have not been made, but for which current investigations show large variations in materials or materials and work classification, have been revised in accordance with the new data. No revision has been made in estimates of features for which new design or investigation work is incomplete. Certain features of the proposed project, to be constructed entirely in Canadian territory, have not been studied by this District since the work would be performed by Canadian authorities. Estimates on these features are based on data received from Canadian Engineers. The new estimates have been based on the general price level of the summer and fall of 1941. Inasmuch as the unit prices of the June 1941 estimate attempted to anticipate the prices of the same period, there is no great difference in the prices for general

items in the two estimates, except in machinery and powerhouse equipment, on which items manufacturers have quoted radically higher prices. However, where detailed take-offs from contract drawings are available, the general items are distributed into individual bid items, in which there are numerous instances of local variations in cost. Another factor which resulted in variation of the estimates is the supply of strategic and critical materials. The design of the various features of the project was started on the basis of the use of ordinary engineering materials, but in the fall of 1941 shortages had developed in many strategic materials, such as paint, copper water stops, rubber seals, aluminum, etc., and numerous revisions were necessary to provide for the use of substitutes or alternate designs. In view of the rapidly changing conditions, it is impossible to forecast the price levels and availability of materials which will exist at time of construction. For this reason, great refinement in estimates is not justified. United States and Canadian works have been estimated on the same prices. All estimates have been based on a program of construction for production of initial power in 44 months, for provision of navigation through the 27-foot locks in 48 months, and for completion of the project in approximately 60 months. The program involves working simultaneously on most of the project features in three shifts throughout, and the maximum possible amount of work during the winter months when construction would normally be severely restricted. Such a program will undoubtedly result in a considerably greater cost than under normal conditions. A still more rapid construction program, as suggested at times, would result in further materially increased cost. Such shortened period would require mobilization of an extremely large amount of plant and equipment and would impose a very heavy load on manufacturers of materials, plant, and equipment. It will be noted that the new estimate is substantially larger than those of the preceding year. For this there are a number of reasons:

a. The new estimate is the first one reflecting the results of the extensive additional surveys and explorations of the previous 17 months. These disclosed the existence of ledge rock in considerable quantities in areas which had previously been assumed to be earth. They also disclosed large amounts of very soft marine clay involving unanticipated difficulties in foundations, cuts and embankments. The more accurate soundings showed the river bed to be somewhat higher than expected, giving a very substantial increase in the amount of excavation in the river channels.

b. Estimates from plans based on surveys and foundations explorations and quotations from manufacturers of hydro-electric equipment have resulted in an increase in cost of about $31,500,000 for "Works Primarily for Power" over the June, 1941 estimate.

c. As a result of hydraulic studies in the Galop Reach, discussed in paragraph 35d, and improvement in channel alignment in the Iroquois to Morrisburg Reach, discussed in paragraphs 37 and 43, in conjunction with revised soundings and subsurface explorations the amount of channel excavation common to navigation and power has been increased. This change has resulted in an increase in cost of about $5,950,000 for the Recommended Plan and would amount to an increase in cost of about

$30,950,000 if the Alternate Plan should be adopted. However, as stated in paragraph 35f either of these plans would result in a gain in head at the powerhouse varying from about 0.2 feet to about 2.6 feet.

d. Foundation investigations revealing deposits of marine clay and relocation of the powerhouse have resulted in a relocation of the Cornwall locks and canal. These conditions have resulted in an increase in cost of about $7,000,000 for this item.

e. About $6,000,000 has been added to the new estimate for items not included in the previous estimate but which are considered essential to the prosecution of the work of construction. These items include, among others, the Village of Seaway to be used as administrative headquarters and for the housing of government employees and the construction and relocation of power facilities for construction purposes.

f. Finally, it must be emphasized that all previous estimates were based on preliminary sketches while most of the items in the current estimate are the results of complete engineering studies, with the solution of all outstanding problems, and the preparation of detailed plans and specifications. This has resulted in higher estimates in some instances where technical difficulties were not fully realized until the complete study was made.

76. NEW ESTIMATES.-Summaries of estimates for each feature of the project have been included in Chapter III, and detailed estimates for these features which have been given more complete study are contained in the appendices. In the preparation of these estimates, allowance for engineering and contingencies has been made at the rate of 18% for features for which contract plans have been prepared; 21% for features revised on the basis of current investigations; and 25% for features with a status equivalent to that of the June 1941 estimate. Summary of the revised detailed estimates by features is given in Table 8 and a recapitulation of these estimates is given in Table 9. The comparative quantities for the June 1941 estimate and the revised (April 1942) estimate for those items for which quantities were of such magnitude as to be of real importance are given in Table 10.

TABLE 8

Project Estimate by Features, April 7, 1942

	Canada	U. S.	Total
A. Works Solely for Navigation		$43,841,000	$43,841,000
I. Upper Pool................		$7,351,000	$7,351,000
Point Rockway Canal & Approach Channels (Feature 7)..........		0	0*
Point Rockway Lock & Attached Dikes (Feature 8)		7,351,000	7,351,000
II. Lower Pool......................		$36,490,000	$36,490,000
Long Sault Canal & Dikes (Feature 16).		8,335,000	8,335,000
Long Sault Canal Guard Gate & Dike #2, (Feature No.17).................		2,997,000	2,997,000
Robinson Bay Lock & Attached Dikes (Feature No.18).................		12,394,000	12,394,000**
Grass River Lock & Attached Dikes (Feature No. 20).................		10,650,000	10,650,000
Relocation of New York Central Railroad & Roosevelt Highway (Feature No. 35).........................		2,114,000	2,114,000

*Excavation of Point Rockway Canal is included in Iroquois Dam and Point Rockway Lock (Features 4 and 8) since the excavated material is to be used in construction of these features. The costs of the canal excavation as included in the estimate of these features are: Iroquois Dam $2,816,000 and Point Rockway Lock $1,707,000, or a total of $4,523,000.

**Includes furnishing miter gate, segmental valve, and wire rope fender machinery for Grass River Lock; wire rope fender and sector gate machinery for Long Sault Guard Gate; wire rope fender machinery for Point Rockway Lock; and spare fender parts for the whole system - all at an estimated cost of $912,016.

	Canada	U. S.	Total
B. Works Primarily for Power	$43,906,000	$104,138,000	$104,044,000
I. Structures, Headrace & Tailrace Excavation.....................		56,647,000	56,647,000
Barnhart Island South Forebay Dike (Feature 23)		1,200,000	1,200,000
Channel Improvement below Barnhart Isld. Powerhouse (Feature 32).............		2,412,000	2,412,000

TABLE 8 (cont.)

Project Estimate by Features, April 7, 1942

	Canada	U.S.	Total
Structures (Structure Items of Feature 24)............		52,467,000	52,467,000
Railway & Highway to Canadian Powerhouse (Feature 29)...		568,000	568,000
II. Machinery & Equipment.......	$43,906,000	$47,491,000	$91,397,000
Machinery & Equipment (Items of Feature 24).............	43,906,000	47,491,000	91,397,000
C. Works Common to Navigation & Power	$22,414,000	124,034,400	$146,448,400
1. Channel Excavation.........		$50,243,400	$50,243,400
Channel Work vicinity Galop Island (Feature 1)........		25,072,200	25,072,200
Channel work Mi. 74-76.5(Feature 3)....................		6,357,200	6,357,200
River work - Point Three Points to Canada Island (Feature 9)		9,409,000	9,409,000
Improvement of South Channel below Mi. 107.4 (Feature 33)		7,066,000	7,066,000
Cornwall Channel Enlargement (Feature 34)...............		2,339,000	2,339,000
2. Ice Cribs (Feature 2).......		$514,000	$514,000
3. Iroquois Dam & Dikes (Feature 4)		$16,057,000	$16,057,000
4. Dikes........................		$910,000	$910,000
Dikes on U.S. side between Waddington and Croil Isld.(Feature 14).........................		735,000	735,000
Minor dikes on Canadian side (Feature 25)...............		175,000	175,000
5. Massena Canal Intake & Attached Dikes (Feature 15)................		5,434,000	$5,434,000
6. Long Sault Dam, Diversion Cuts, & Attached Dikes (Feature 22)		$19,553,000	$19,553,000
7. New Cornwall Canal		$11,190,000	$11,190,000

TABLE 8 (cont.)

Project Estimate by Features, April 7, 1942

	Canada	U. S.	Total
Canal dike, north powerhouse embankment and drainage ditch (Feature 26).................		3,735,000	3,735,000
Cornwall Canal Relocation (Feature 27).....................		435,000	435,000
Lock & Guard Gate (Feature 28)		7,020,000	7,020,000
8. Work at Lock 25 (Feature 5)...		$ 604,000	$ 604,000
9. Railroad Relocation		$ 3,699,000	$ 3,699,000
Norwood & St. L. Railroad (Feature 13).....................		261,000	261,000
Canadian National Ry. (Feature 30)		3,438,000	3,438,000
10. Clearing Pool (Feature 39).....		$ 500,000	$ 500,000
11. Rehabilitation of Morrisburg (Feature 11)..................	$5,024,000		$ 5,024,000
12. Rehabilitation of Iroquois (Feature 6)....................	3,379,000		$ 3,379,000
13. Acquisition of Lands...........	$14,011,000	$ 6,200,000	$20,211,000
U.S. (Incl. Features 10 & 37)..		6,200,000	6,200,000
Canada (Feature 38)............	14,011,000		14,011,000
14. Highway Relocation.............		$2,974,000	$2,974,000
U. S. Highways-Massena to Waddington (Feature 12)................		849,000	849,000
Kings Highway No. 2 (Feature 31)		2,125,000	2,125,000
15. Raising Lock 21 & Dikes (Feature 22).		$ 125,000	$ 125,000
16. Seaway Village (Feature 21.........		$5,650,000	$5,650,000
17. Power Distribution Facilities for Construction (Feature 21)...........		$ 217,000	$ 217,000
18. Relocation of St. Lawrence River Power Company Transmission Line over Robinson Bay Lock and Powerhouse (Feature 36)...		$ 164,000	$ 164,000

TABLE 9

RECAPITULATION OF PROJECT ESTIMATE, APRIL 7,1942

		Canada	U.S.	Total
A.	Works Solely for Navigation			
I.	Upper Pool		$ 7,351,000	
II.	Lower Pool		36,490,000	$ 43,841,000
B.	Works Primarily for Power			
I.	Structures, Headrace & Tailrace Excavation		56,647,000	
II.	Machinery & Equipment	$43,906,000	47,491,000	148,044,000
C.	Works Common to Navigation & Power			
1.	Channel Excavation		50,243,400	
2.	Ice Cribs		514,000	
3.	Iroquois Dam & Dikes		16,057,000	
4.	Dikes (Detached Dikes)		910,000	
5.	Massena Canal Intake & Attached Dikes		5,434,000	
6.	Long Sault Dam, Diversion Cuts & Attached Dikes		19,553,000	
7.	New Cornwall Canal		11,190,000	
8.	Work at Lock 25		604,000	
9.	Railroad Relocation		3,699,000	
10.	Clearing Pool		500,000	
11.	Rehabilitation of Morrisburg	5,024,000		
12.	Rehabilitation of Iroquois	3,379,000		
13.	Acquisition of Lands	14,011,000	6,200,000	
14.	Highway Relocation		2,974,000	
15.	Raising Lock 21 & Dikes		125,000	
16.	Seaway Village		5,650,000	
17.	Power Distribution Facilities for Construction		217,000	
18.	Relocation of Transmission Lines		164,000	
				146,448,400
	TOTAL.......	$66,320,000	$272,013,400	$338,333,400

Under the International Agreement of March 19, 1941, the cost chargeable to power would be as follows:

All of "B".......................	$148,044,000
Half of "C"......................	73,224,200
Total charged to power...	$221,268,200

The cost chargeable to navigation would be:

All of "A".......................	$ 43,841,000
Half of "C"......................	73,224,200
Total charged to navigation..........	$117,065,200

TABLE 10

COMPARISON OF QUANTITIES IN ESTIMATES OF JUNE, 1941 AND APRIL, 1942

Estimate of June, 1941

	Concrete (All Classes) c. y.	EXCAVATION Earth, Dry c. y.	Earth, Wet c. y.	Rock, Dry c. y.	Rock, Wet c. y.	Total Exc. c. y.	FILL Earth c. y.	Rock c. y.	Total Fill c. y.
Iroquois Dam and Dikes *	254,500	448,000		24,900		472,900	210,000	96,000	306,000
Point Rockway Canal		2,992,700	255,000			3,247,700	668,200	43,700	711,900
Point Rockway Lock & Dikes	353,784	1,224,805		43,854		1,268,659	1,387,559		1,387,559
Massena Canal Intake & Dikes *	91,210	1,026,144	120,700	5,930		1,152,774	832,768	61,371	894,139
Long Sault Canal & Dikes		5,743,300	1,269,800			7,013,100	7,008,900	553,233	7,562,133
Long Sault Guard Gate & Dikes	97,957	571,892				571,892	242,915		242,915
Robinson Bay Lock & Dikes	522,524	1,876,522		30,565		1,907,087	2,135,859		2,135,859
Grass River Lock & Dikes	363,860	1,929,092		28,340		1,957,432	1,630,702		1,630,702
Long Sault Dam & Dikes *	642,400	2,997,789	350,000	287,800		3,635,589	223,954	18,002	241,956
Miscellaneous Dikes		433,110				433,110	6,014,458	219,549	6,234,007
New Cornwall Lock & Guard Gate	172,585	405,533		13,608		419,141	743,307		743,307
Channel Excavation common to Navigation and Power		21,885,100	15,606,700	2,879,600	402,550	40,773,950			
Barnhart Is. Powerhouse including Tailrace Excavation, Crab Is. Shoal Excavation, and South Forebay Dike *	1,509,000	7,493,200	1,837,500	497,620		9,828,320	697,775	48,210	745,985
Totals	4,007,820	49,027,187	19,439,700	3,812,217	402,550	72,681,654	21,796,397	1,040,065	22,836,462

Estimate of April, 1942

	Concrete (All Classes) c. y.	EXCAVATION Earth, Dry c. y.	Earth, Wet c. y.	Rock, Dry c. y.	Rock, Wet c. y.	Total Exc. c. y.	FILL Earth c. y.	Rock c. y.	Total Fill c. y.
Iroquois Dam and Dikes *	243,500	757,200		32,000		789,200	211,500	65,400	270,900
Point Rockway Canal		2,412,000		928,000		3,340,000			
Point Rockway Lock & Dikes	272,550	3,588,000		516,000		4,104,000	748,900	49,000	797,900
Massena Canal Intake & Dikes *	92,500	1,513,000		11,900		1,524,900	1,535,000	97,600	1,632,600
Long Sault Canal & Dikes		15,906,000				15,906,000	3,342,000	193,000	3,535,000
Long Sault Guard Gate & Dikes	131,000						410,650	65,700	476,350
Robinson Bay Lock & Dikes	497,300	3,313,000		20,000		3,333,000	2,704,000	50,400	2,754,400
Grass River Lock & Dikes	386,750	7,973,000		18,000		7,991,000	1,747,900	38,300	1,786,200
Long Sault Dam & Dikes *	583,500	3,980,000		85,000		4,065,000	303,300	34,800	338,100
Miscellaneous Dikes		350,799				350,799	5,991,311	260,207	6,251,518
New Cornwall Lock & Guard Gate	383,000	686,000		25,330		711,330	666,000	128,000	794,000
Channel Excavation common to Navigation and Power		28,650,000	20,698,400	1,691,000	579,000	51,618,400			
Barnhart Is. Powerhouse including Tailrace Excavation, Crab Is. Shoal Excavation, and South Forebay Dike *	1,918,000	4,071,000	1,837,500	225,000		6,133,500	2,092,900	316,000	2,408,900
Totals	4,508,100	73,199,999	22,535,900	3,552,230	579,000	99,867,129	19,753,461	1,298,407	21,051,868

* Does not include cofferdams.

TABLE 11

SCHEDULE OF EXPENDITURES BY FISCAL YEARS

	First Year		Second Year	Third Year	Fourth Year	Fifth Year	Sixth Year	Total
	Preliminary Funds	Construction						
United States	$8,657,000	$14,721,800	$67,771,400	$76,564,800	$58,579,600	$31,228,900	$14,489,900	$272,013,400
Canada	0	2,582,000	5,485,000	13,212,000	16,515,000	19,388,000	9,138,000	66,320,000
Total	$8,657,000	$17,303,800	73,256,400	89,776,800	75,094,600	$50,616,900	$23,627,900	$338,333,400

77. <u>SCHEDULE OF EXPENDITURES.</u>- A schedule of expenditures by fiscal years for the complete project has been prepared, based on a work schedule providing initial power in 44 months, and 27-foot navigation in 48 months. This schedule, shown in Table 11, contemplates that preliminary work and award of contracts will be initiated about January 1 of the first fiscal year of construction, and that actual construction will start about April 1 of the same year. Preliminary funds as shown will be required at the beginning of the work on January 1 of the first year.

A. B. Jones

A. B. JONES,
Colonel, Corps of Engineers,
District Engineer.

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

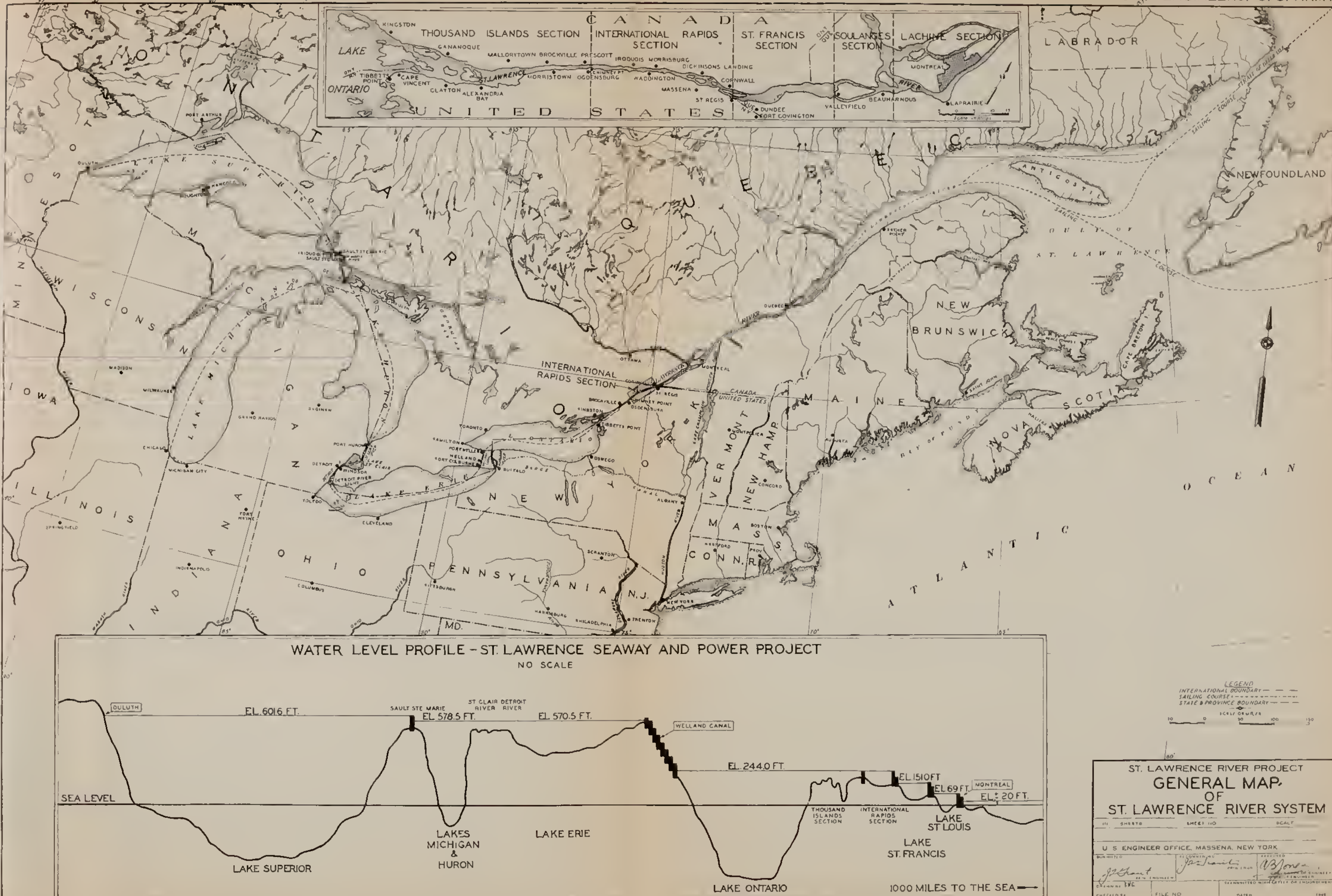


PLATE M

WAR DEPARTMENT

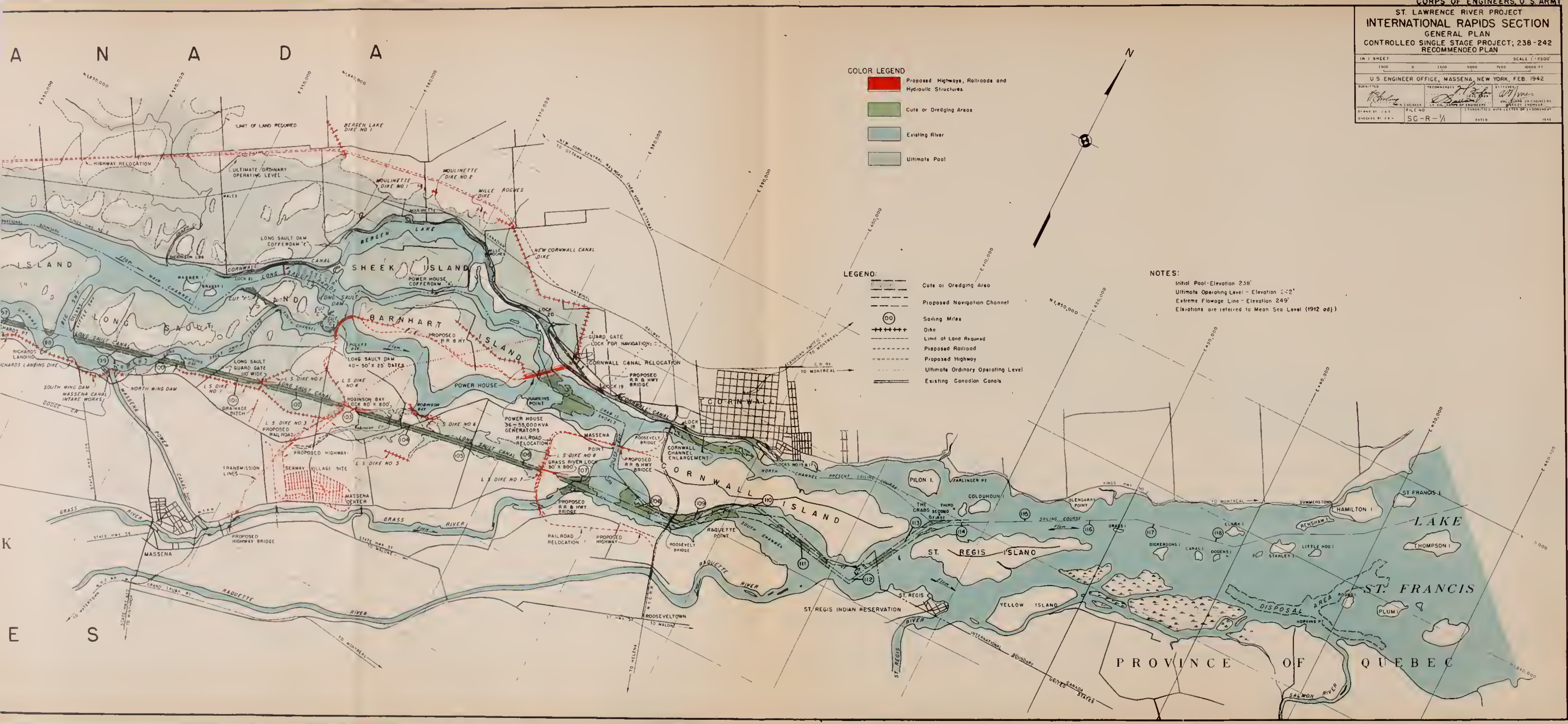

CORPS OF ENGINEERS, U.S. ARMY
ST. LAWRENCE RIVER PROJECT
INTERNATIONAL RAPIDS SECTION
GENERAL PLAN
CONTROLLED SINGLE STAGE PROJECT; 238-242
RECOMMENDED PLAN
U.S. ENGINEER OFFICE, MASSENA, NEW YORK, FEB. 1942
SG-R-1/1
COLOR LEGEND
Proposed Highways, Railroads and Hydraulic Structures
Cuts or Dredging Areas
Existing River
Ultimate Pool
LEGEND:
Cuts or Dredging Area
Proposed Navigation Channel
Sailing Miles
Dike
Limit of Land Required
Proposed Railroad
Proposed Highway
Ultimate Ordinary Operating Level
Existing Canadian Canals
NOTES:
Initial Pool-Elevation 238'
Ultimate Operating Level - Elevation 242'
Extreme Flowage Line - Elevation 249'
Elevations are referred to Mean Sea Level (1912 adj.)
N
CANADA
UNITED STATES
PROVINCE OF QUEBEC
SHEEK ISLAND
BARNHART ISLAND
CORNWALL ISLAND
ST. REGIS ISLAND
LONG SAULT ISLAND
BERGEN LAKE
LAKE ST. FRANCIS
CORNWALL
MASSENA
ST. REGIS
ST. REGIS INDIAN RESERVATION
GRASS RIVER
RAQUETTE RIVER
ST. REGIS RIVER
SALMON RIVER
LONG SAULT CANAL
CORNWALL CANAL
POWER HOUSE
LONG SAULT DAM 40-50' x 25' GATES
POWER HOUSE 36-55,000 KVA GENERATORS
GRASS RIVER LOCK 80' x 800'
ROBINSON BAY LOCK 80' x 800'
NEW CORNWALL CANAL DIKE
CORNWALL CANAL RELOCATION
CORNWALL CHANNEL ENLARGEMENT
SEAWAY VILLAGE SITE
MASSENA CENTER
HIGHWAY RELOCATION
RAILROAD RELOCATION
PROPOSED HIGHWAY
YELLOW ISLAND
PILON I.
THOMPSON I.
HAMILTON I.
ST. FRANCIS I.
ROOSEVELTOWN
DISPOSAL AREA

PLATE M-1


WAR DEPARTMENT
N
DOMINION OF C
PROVINCE OF ONTARIO
STATE OF NEW YOR
UNITED STAT
GOOSE NECK ISLAND
OGDEN ISLAND
GALOP ISLAND
MURPHY ISLAND
MORRISBURG
WADDINGTON
IROQUOIS
CARDINAL
JOHNSTOWN
RED MILLS
TILDEN
CAT ISLAND
LOUISVILLE LANDING
RAILWAY RELOCATION
HIGHWAY RELOCATION
ULTIMATE ORDINARY OPERATING LEVEL
LIMIT OF LAND REQUIRED
IROQUOIS DAM 40-50' X 48' GATES
POINT ROCKWAY CANAL
COLES CREEK DIKE

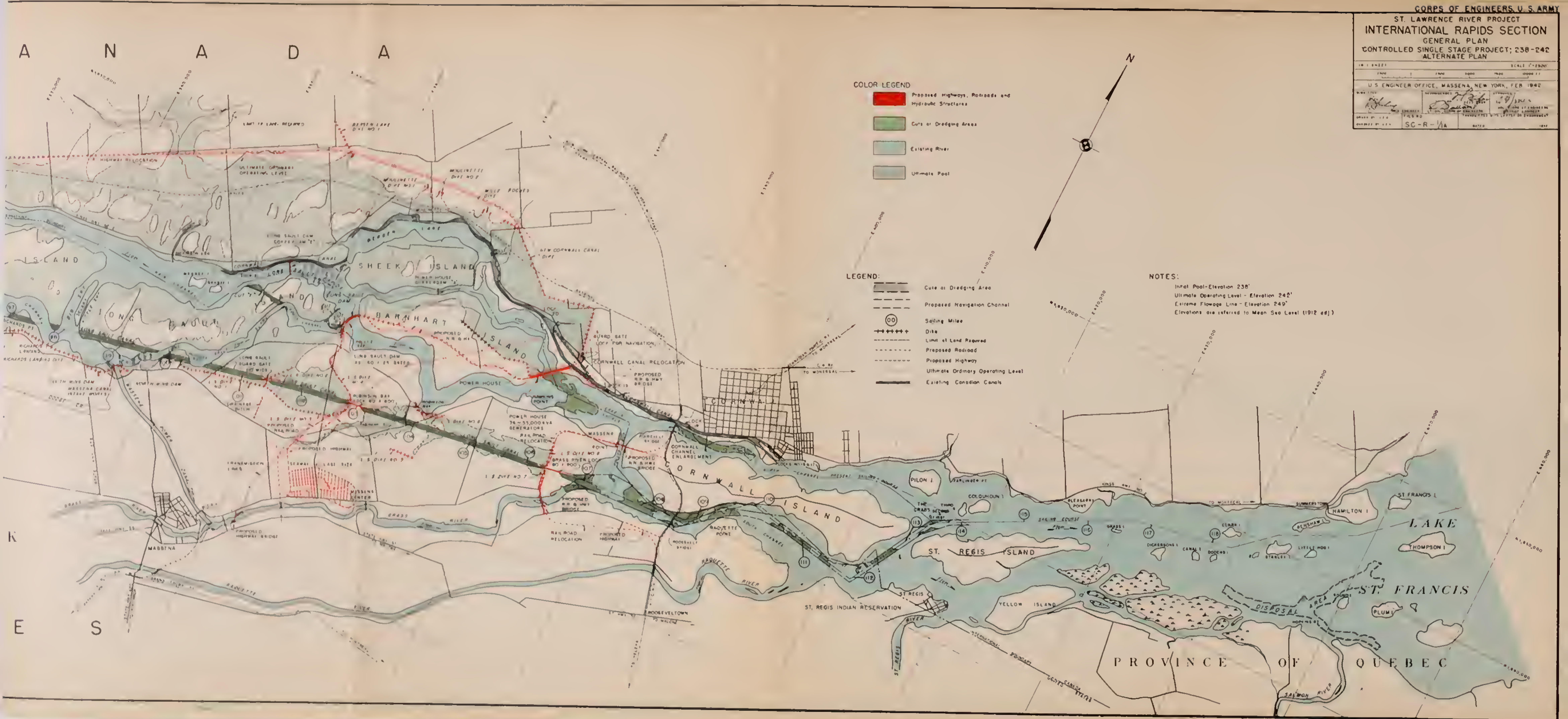
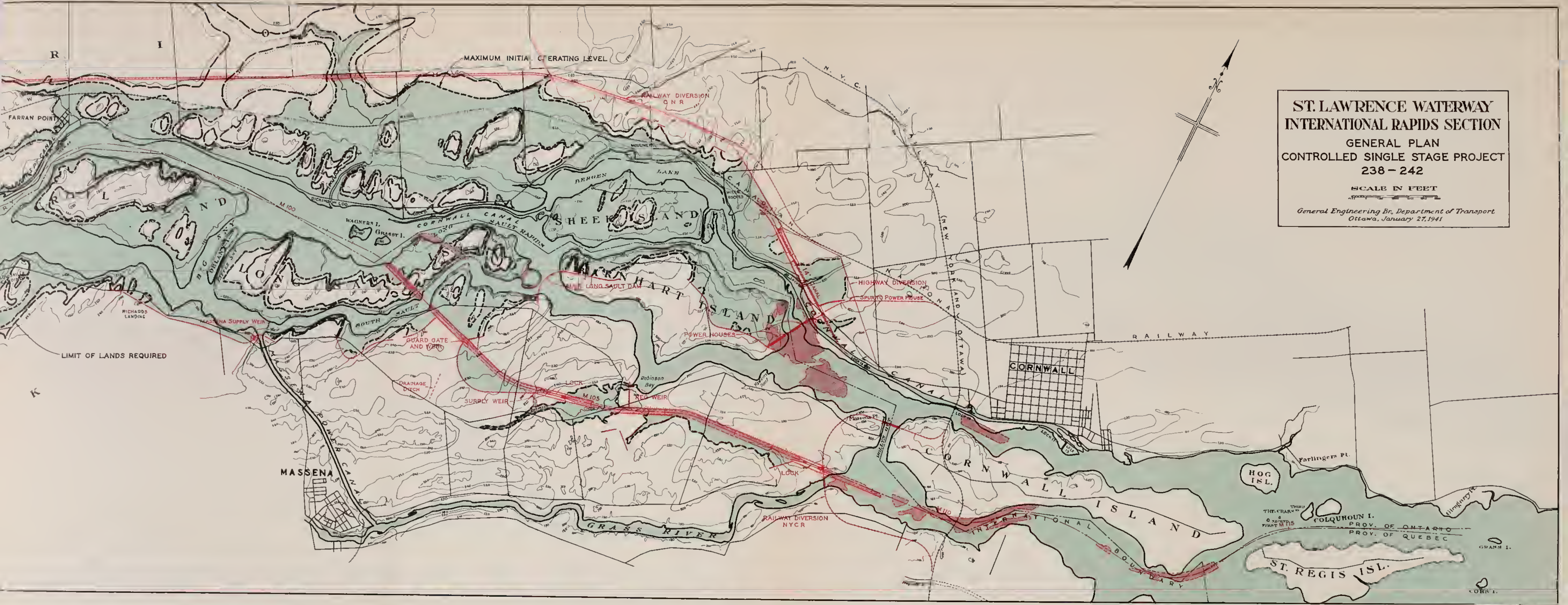
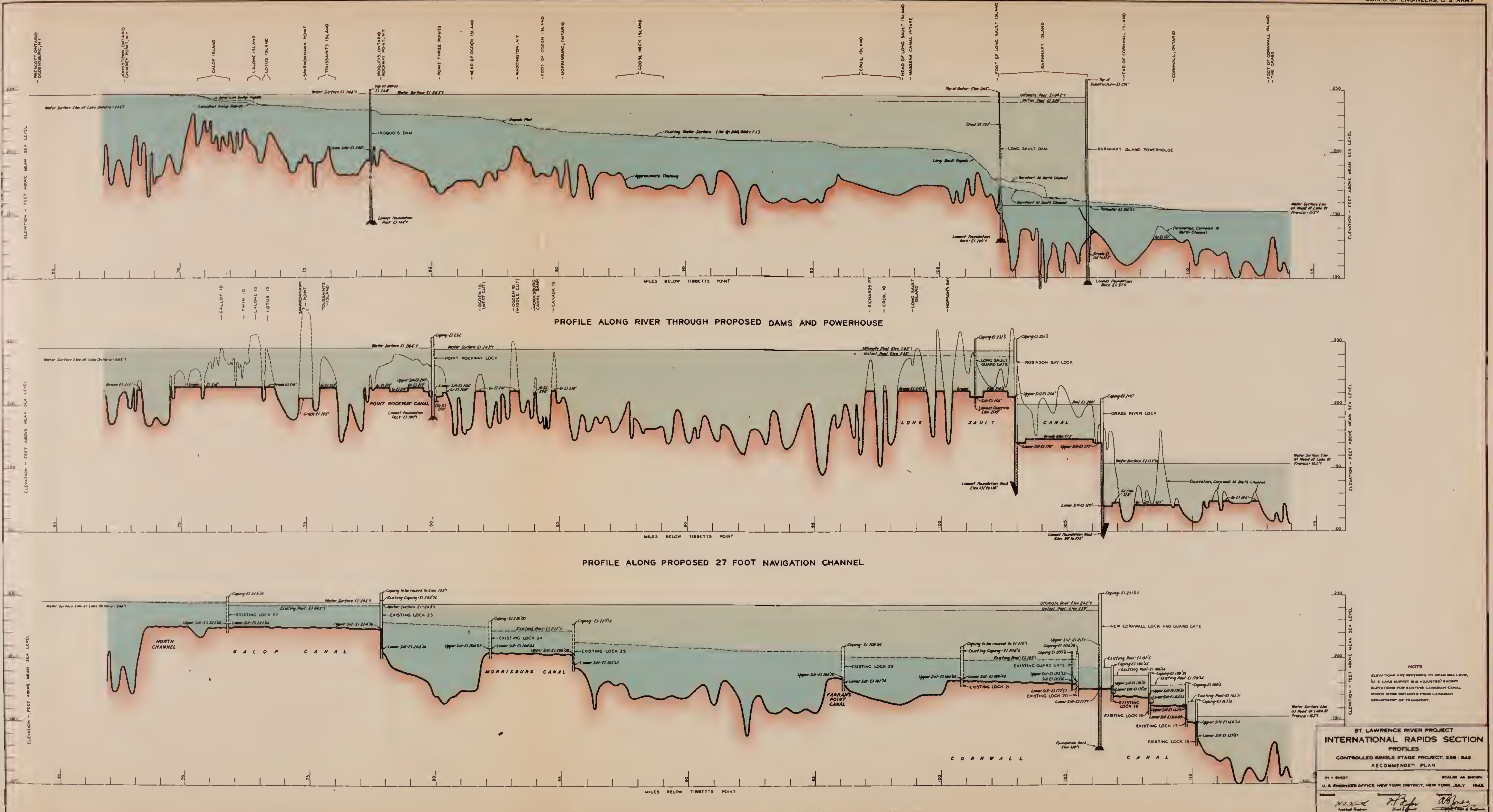

CORPS OF ENGINEERS, U. S. ARMY
ST. LAWRENCE RIVER PROJECT
INTERNATIONAL RAPIDS SECTION
GENERAL PLAN
CONTROLLED SINGLE STAGE PROJECT; 238-242
ALTERNATE PLAN
U.S. ENGINEER OFFICE, MASSENA, NEW YORK, FEB 1942
SC-R-1/1A
COLOR LEGEND
Proposed Highways, Railroads and Hydraulic Structures
Cuts or Dredging Areas
Existing River
Ultimate Pool
LEGEND:
Cuts or Dredging Area
Proposed Navigation Channel
Sailing Miles
Dike
Limit of Land Required
Proposed Railroad
Proposed Highway
Ultimate Ordinary Operating Level
Existing Canadian Canals
NOTES:
Initial Pool-Elevation 238'
Ultimate Operating Level - Elevation 242'
Extreme Flowage Line - Elevation 249'
Elevations are referred to Mean Sea Level (1912 adj.)
N
C A N A D A
SHEEK ISLAND
BARNHART ISLAND
POWER HOUSE
CORNWALL CANAL RELOCATION
CORNWALL
CORNWALL ISLAND
ST. REGIS ISLAND
ST. REGIS INDIAN RESERVATION
PILON I.
YELLOW ISLAND
HAMILTON I.
ST. FRANCIS I.
THOMPSON I.
LAKE ST. FRANCIS
DISPOSAL AREA
MASSENA
RAQUETTE RIVER
ROOSEVELTOWN
PROVINCE OF QUEBEC
E S

PLATE M-1A

PROVINCE OF ONTARIO
STATE OF NEW YORK
LIMIT OF LANDS REQUIRED
RAILWAY DIVERSION C.N.R.
HIGHWAY DIVERSION
MAXIMUM INITIAL OPERATING LEVEL
MORRISBURG
WADDINGTON
CARDINAL
LISBON
TILDEN
AULTSVILLE
E. WILLIAMSBURG
14 FT LOCK
CONTROL DAM
LOCK
CANADIAN NATIONAL RAILWAY
INTERNATIONAL BOUNDARY
MORRISBURG CANAL
GALOP CANAL
GALOP RAPIDS
OGDEN ISL.
GOOSE NECK ISLAND
CLARK ISL.
DOBAN ISL.
STRAWBERRY ISL.
CRYSLER ISL.
CAT ISL.
CHIMNEY ISL.
DRUMMOND PT.
ICE CRIBS AND BOOMS
RAILWAY DIVERSION N. & ST. L. R.
Little Sucker Brook
Brandy Brook
ST. LAWRENCE


ST. LAWRENCE WATERWAY
INTERNATIONAL RAPIDS SECTION
GENERAL PLAN
CONTROLLED SINGLE STAGE PROJECT
238 – 242
SCALE IN FEET
General Engineering Br., Department of Transport
Ottawa, January 27, 1941
MAXIMUM INITIAL OPERATING LEVEL
FARRAN POINT
RAILWAY DIVERSION
C N R
CORNWALL CANAL
LONG SAULT RAPIDS
SHEEK ISLAND
BARNHART ISLAND
LONG SAULT DAM
HIGHWAY DIVERSION
SPUR TO POWER HOUSE
POWER HOUSES
RAILWAY
CORNWALL
CORNWALL ISLAND
MASSENA SUPPLY WEIR
GUARD GATE AND WEIR
LIMIT OF LANDS REQUIRED
DRAINAGE DITCH
SURPLY WEIR
LOCK
REG WEIR
Robinson Bay
MASSENA
MASSENA POWER CANAL
GRASS RIVER
RAILWAY DIVERSION
NYCR
INTERNATIONAL BOUNDARY
HOG ISL.
Farlingers Pt.
COLQUHOUN I.
PROV. OF ONTARIO
PROV. OF QUEBEC
ST. REGIS ISL.
N. Y. C.
NEW YORK AND OTTAWA



PROFILE ALONG RIVER THROUGH PROPOSED DAMS AND POWERHOUSE

PROFILE ALONG PROPOSED 27 FOOT NAVIGATION CHANNEL

PROFILE ALONG EXISTING CANADIAN CANALS AFTER DEVELOPMENT IS COMPLETED

NOTE

ELEVATIONS ARE REFERRED TO MEAN SEA LEVEL (U. S. LAKE SURVEY 1935 ADJUSTED) EXCEPT ELEVATIONS FOR EXISTING CANADIAN CANAL WHICH WERE OBTAINED FROM CANADIAN DEPARTMENT OF TRANSPORT.

ST. LAWRENCE RIVER PROJECT

INTERNATIONAL RAPIDS SECTION

PROFILES

CONTROLLED SINGLE STAGE PROJECT: 238-242

RECOMMENDED PLAN

IN 1 SHEET — SCALES AS SHOWN

U. S. ENGINEER OFFICE, NEW YORK DISTRICT, NEW YORK, JULY 1942.

FILE NO. SC-8-1/4